December 1986/January 1987

AIR&SPACE

Smithsonian

The F-16 "electric" jet—
a computer wrapped around a pilot


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-IDLING
-LOW TANK
-FULL TANK
-UNKNOWN
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December 1986/January 1987 Volume 1, Number 5

AIR & SPACE
Smithsonian

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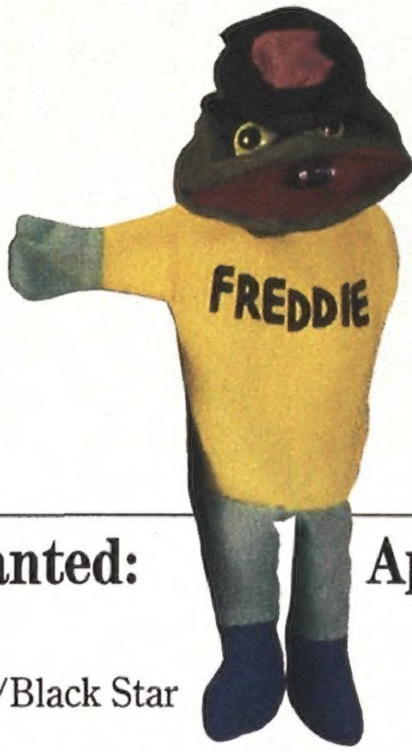
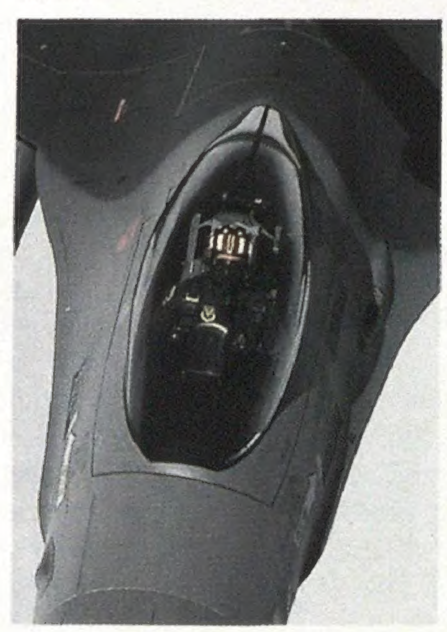


Cover: *The lucky pilot of a U.S. Air Force F-16 looked up to see George Hall and his camera during a rendezvous with an aerial tanker.*



Reach out and Teach Someone

The nationwide decline in enrollment in mathematics and science courses in secondary schools, coupled with a slackening in the quality of the courses offered in these fields, poses serious problems for the United States. The immediate effect of the downturn is a decrease in the number of college graduates with degrees in math and science. But in the long term, the nation's ability to maintain its stature as a leader among the industrialized nations in key areas of aerospace science and technology will be impaired.

Not so long ago, aerospace sciences tended to be concentrated in national centers of industry, and the United States was the proud home of the most prominent of these. But that concentration has given way to diffusion: aerospace has begun to breach its former national boundaries and has burst forth into global enterprises characterized by complex international relationships. The change has come about partly because the cost of aerospace projects has increased markedly. But more importantly, other nations have been investing steadily in their futures by fostering high-quality education in science and mathematics, and that effort has paid off.

In a recent international test of the mathematical skills of high school students, the United States trailed all the industrialized nations and led only Third World countries. That gloomy result came as no surprise. The Europeans, Japanese, and Soviets have strong programs in science and mathematics at all levels in their educational systems, with the predictable result.

The way to entice more U.S. high school and college students to pursue science and math may be to help them see the connection between learning and the fruits of knowledge. The National Air and Space Museum can be a primary force to incite interest in aerospace science and technology. The artifacts within the NASM collection are emblematic of the accomplishments of earlier generations that found inspiration in flight without needing to be led to it. From the balcony of the Pioneers of Flight Gallery, one can see the magnitude of achievement in the Wright *Flyer*, the *Spirit of St. Louis*, the Bell X-1, the Sputnik, Explorer, and Mariner satellites, and the Apollo 11 command module.

A visit to the Museum is an effective way to motivate, but only a small segment of the nation's students has access to it. For others, science teachers can make the difference, and NASM's Education Department has established several programs to support teachers in this effort.

Workshops are presented by the NASM staff and other professionals on aviation, space, science, and technology. These workshops, typified by the recent "Looking at Earth" series, incorporate NASM's collection, historical information, and hands-on activities for educators to share with their students. Curriculum materials are designed to integrate the exhibits and artifacts into a coherent plan to teach the history of the quest for flight. Once students can envision the reward, the motivation to study follows naturally.

The Museum's Regional Resource Program has trained and regularly provides material to a nationwide network of 73 aviation and space enthusiasts, primarily teachers, who speak to schools and other organizations within their geographical areas, and this program is being expanded to provide greater coverage.

With the cooperation of the National Aeronautics and Space Administration, the Museum is establishing an Education Resource Center to help update textbooks with a continuing stream of current information. Teachers can obtain timely resource materials on aviation and space, including audio-visual packages, lesson plans, and other information to enhance the teaching of science and technology.

The interest in aerospace is there. The consistently high attendance at the Museum proves it. The challenge to educators is to make use of the opportunity afforded by this spontaneous interest and generate an equally strong motivation to study the mathematics and science that form the educational foundation upon which our future will depend.

—Donald Lopez
Deputy Director, NASM

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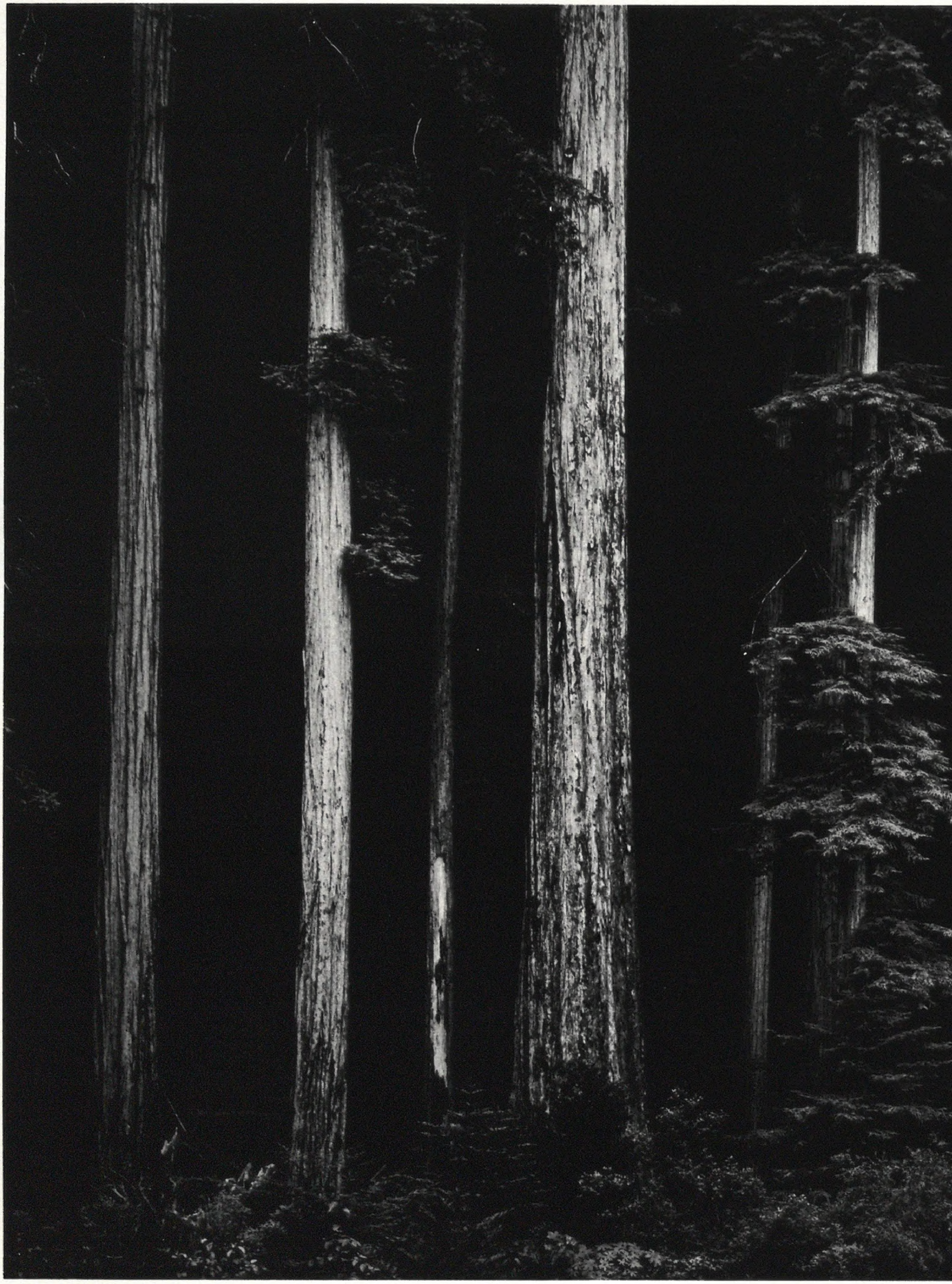
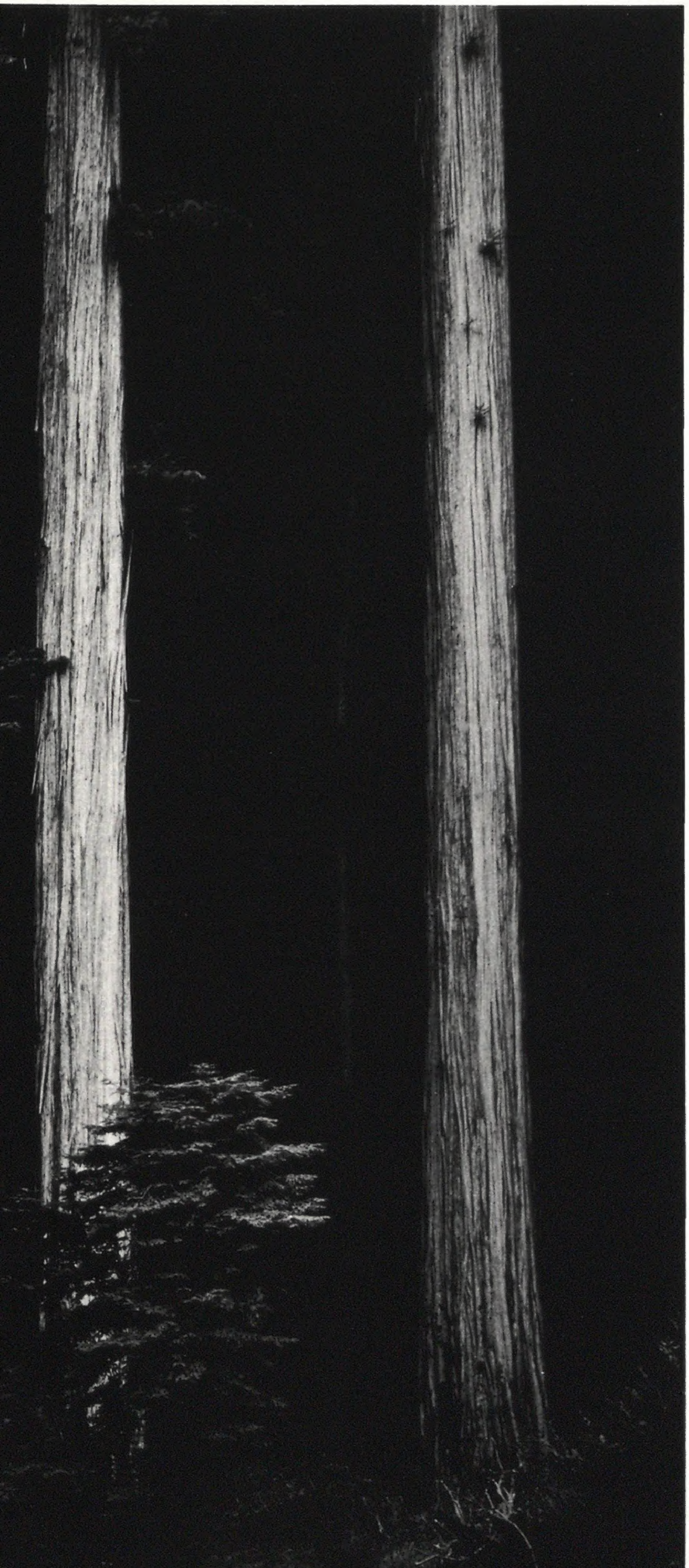


Like the California Redwoods, NASA's Space Shuttle is a national resource.



Redwoods, Bull Creek Flat, Northern California. Photograph by Ansel Adams. Courtesy of The Trustees of The Ansel Adams Publishing Rights Trust.

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Letters

Here There Be Dragonflies

The article on the dragonfly ("The Flight of the Dragonfly," October/November 1986) was interesting, but I had to wonder why Bill Stout's name was never mentioned.

About 30 years ago I heard Mr. Stout speak at a meeting sponsored by the American Institute of Aeronautics and Astronautics' predecessor. His message was that a bird's wing was just too complicated to duplicate because of all the feather action, but there was hope for accomplishing flight with an insect-type wing. He called his could-be vehicle the *Giganticus gerflopagus,* with flexible membrane wings supported by a spar near the leading edge. I believe he patterned his concepts after the dragonfly, too. He also had an ice-scooter propelled by a couple of wings.
Walter J. Klinar
Alvin, Texas

Four frames of a prehistoric dragonfly and we see a menu of most of the worthwhile wing designs known to man: forward sweep, variable sweep, stagger, tilt, high lift, canard, super critical, and delta wing configurations, with pulsed power thrown in as a bonus.

Hopefully Marvin Luttges and his colleagues will devise a means of recording this marvelous little airframe in free flight. A study of its maneuvering techniques and configurations will surely save design engineers much trial and error for years to come.
J. Michael Mooney
Talimena, Oklahoma

Personality Crisis

I think *Air & Space/Smithsonian* is suffering an identity crisis. It isn't quite sure if it should cover history or current events, machines or themes—and ultimately winds up being a generic magazine with tepid articles on subjects that have already been covered in other publications and even on TV. I appreciate the desire to present "living" history in addition to articles on past events, but I also think that there are enough magazines covering aviation current events.

Air & Space/Smithsonian needs to get knee-deep in aviation. It's in danger of becoming to aviation what *Newsweek* is to current events—style over substance. A great museum deserves a better magazine.
William H. Longyard
Clemmons, North Carolina

Fly-Through Windows

Mitchel Zoler's article about McGehee's Catfish Restaurant ("Soundings," October/November 1986) brought back some memories of a similar establishment in the largest state *east* of the Mississippi.

About 25 years ago I was working in the old control tower at Daniel Field in Augusta, Georgia. Located at the perimeter fence, just past the junction of the two "live" runways, was a restaurant called Timmerman's, which billed itself as "The World's Only Fly-in, Drive-in Restaurant." I guess they could have added "walk-in," too, because several times a week a group of us would walk down the tie-down area for lunch. Timmerman's had been in business for some time even then, and was still, some ten or twelve years ago. I haven't been that way lately, but if they're still there, it looks like their slogan needs to be changed from "only" to "oldest."
James C. Moore
Alexandria, Virginia

Pilot Wail

I'm deeply concerned about the line of thought supported in "The Great American Pilot Shortage" (October/November 1986). The last thing we need in this country is another form of governmental meddling in the free enterprise system.

In the past there was no problem filling the ranks of professional pilots simply because the possibility of a rewarding career with a major airline offset the risks involved in becoming qualified for such a job. With today's outlook consisting of contrived

bankruptcies, two-tier pay scales, and the uncertainty of company mergers, who can blame prospective pilots for not wanting to invest the years and dollars that have always been necessary to obtain what, in the past, has been one of the greatest careers available? There are plenty of piloting jobs in the world; there just aren't as many worth having.
Joseph S. Persinger, Jr.
Lookout Mountain, Tennessee

Aspiring pilots may still be turned on by the dream of flight, but an airline career has turned that dream into a nightmare. Traditional rewards, psychic and financial, have been drastically reduced in management's quest for lower ticket prices at any cost. The public, looking for cheap travel, has supported airlines that use the loopholes of deregulation to break contracts, hide behind Chapter 11 bankruptcy, and hire flight and ground crews willing to work for substandard wages.

When was the last time you saw an ad touting the experience of an airline employee? Today they stress low fares or frequent flyer programs. It's what the public wants, so job status suffers along with pay and benefits, while job stability is at an all-time low.

Throwing money at the problem in the form of free training will not produce dedicated professionals. What is needed to attract motivated, qualified people is a challenging career that offers an attractive cost-risk-reward package, and recognition for a job well done. The alternative is accepting lower and lower standards from applicants. And you'd have to believe in the tooth fairy to think that's not going to affect safety.
Walt Darran
Rancho California, California

I read "The Great American Pilot Shortage" and am very interested in becoming a pilot. I would like as much information as possible on the Future Aviation Professionals of America mentioned in the article.
Jason Coleman
Humboldt, Tennessee

To reach the Future Aviation Professionals of America, write to the manager of their information center, Molly Brown, at 4291-J Memorial Drive, Decatur, Ga. 30032.

Up, Up, and Away

While I can understand Mr. Aaronson's enthusiasm over the prospect of utilizing the tilt-rotor aircraft from shuttle ports to re-

duce congestion in and around northeast airports ("Soundings," October/November 1986), I must be a little more pessimistic.

As an air traffic controller who works the congested northeast corridor, the tilt-rotor appears to me a means of taking the 120 passengers in a DC-9 or 727 and putting them into three or four smaller tilt-rotors, thereby increasing our workload threefold. Thanks, but no thanks. The airspace in the East is already bursting at the seams from the eruption of commuter airlines since deregulation. I'm afraid any more dispersing of passengers would be more than the system could handle. While these commuter aircraft may look small on the ground next to a behemoth like a 747, they nevertheless receive just as large a piece of the sky for traffic separation purposes.

The tilt-rotor may indeed reduce automobile congestion at the major airports, but it will still be a matter of "hurry up and wait" because these aircraft will also have to wait for a departure slot. Perhaps the answer is not more airplanes carrying fewer people, but fewer airplanes carrying more people.

Thomas McCarthy
Sterling, Virginia

You Must Remember This

I greatly enjoyed your article on the DC-3 ("Something Special in the Air") in the October/November issue. However, the aircraft shown in *Casablanca* was not a DC-3, but rather a Lockheed Electra (the original Electra, not the 1950s turboprop).

John M. Whitlock
Richmond, Virginia

A warm thank you for your DC-3 and Piper Cub features ("Soundings," October/November 1986). May such nostalgic glances back respectfully remind space enthusiasts that we had to walk before we could run.

Gail J. Erwin
New York, New York

Three cheers for the fine article about the fabulous DC-3. The DC-3 is fifty years young and still flying! Unbelievable, isn't it?

Every time this frequent flyer boards a Douglas jetliner, I feel that the proud heritage of the DC-3 is very apparent.

Margaret Nowacki
Rolling Meadows, Illinois

As an aviator, I particularly enjoyed reading the article on the faithful DC-3. My earliest childhood recollection of an aircraft was of the DC-3, or "Dakota." I was only three and living in Kenya when my parents identified and pointed out the aircraft flying over our farm en route from Uganda. From then on, the familiar purring of the Pratt and Whitney radial engines made me look skyward and shout, "Dakota."

Since then I have seen many DC-3s. I'm still awed by them and I dream of the occasion that I'm able to fly one as pilot-in-command.

John Andrew Kerr
Bisbee, Arizona

Feeling His Oaths

In "A Cosmonaut's Odyssey" ("Moments and Milestones," October/November 1986), "Twice Hero of the Soviet Union, Pilot-Cosmonaut of the U.S.S.R." Lebedev records, "We swore an oath. . . . "

Can one who does not believe in God swear? I checked my own recollection, and *The Oxford Universal Dictionary* agrees, that an oath is "a solemn appeal to God (or to something sacred) in witness."

Perhaps Lebedev does believe in God and/or sacred things. Perhaps Heroes of the Soviet Union are permitted to swear.

Charles Crabbe Thomas
Woodbury, New Jersey

Dragging Along

In response to Kevin O. Brennan's complaint about the article on drag racing ("Letters," October/November 1986), I agree he's a "drag." I'd like to know what he thinks those dragsters move through? What makes a windmill work? How can he suggest windmills have nothing to do with air when a windmill's purpose is to turn moving air into power for our use? Must we limit ourselves to airplanes and spacecraft? How dull!

I'd like to suggest to Mr. Brennan that if you don't like a particular article's subject, don't read it.

I for one congratulate *Air & Space/Smithsonian* for giving great diversity and interest to a magazine that could be a drag.

Cynthia Cathcart
Silver Spring, Maryland

Air & Space/Smithsonian *welcomes comments from its readers. Letters must be signed and may be edited for publication. Address letters to* Air & Space/Smithsonian, *National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560.*

"In a moment, on the right, you'll see Captain Barlow's begonias in a blue window box."

Once an Eagle . . .

It had been a terrible landing, she insisted. As we walked across the ramp at Ephrata Airport in Washington, I assured my young cousin Sheryll that she'd made a fine landing—we were alive, weren't we?

What I didn't say was that the entire flight from Seattle in the two-seat Cessna 150 had been a trial for me. The little trainer felt flimsy. Worse, our top speed during the entire grind had been no more than 90 mph. Years ago, when I'd flown in the Air Force, our high-performance fighters would stall and quit flying at twice that speed. All the way to Ephrata, my mental stall-warning horn had been wailing steadily. Though my anxiety hadn't been caused by any fault of Sher's, she'd picked up on it and had blamed her flying.

Les Weaver, Sher's husband and president of the Washington State chapter of the International Aerobatic Club, met us on the ramp. "They should be here any minute," he said. Sure enough, a faint drone came from the north. We scanned the sky, using our hands to shade our eyes from the glare of the afternoon sun.

"There," Sher said, pointing at five specks low on the horizon. They drew closer, and we could see they were in an echelon formation, ready to break and circle to land. They passed overhead, and the once-silent airport erupted in noise.

"Go, guys!" Sher yelled.

Les checked his watch. "That's the Seattle bunch," he said. As they taxied in, three more buzzed overhead and fanned out to land. "Those must be Canada."

The first biplane in was a beauty, brilliant in the pale sun. The pilot cut off the engine, opened the bubble canopy, and waved as the propeller dithered to a stop, one blade pointing to the sky. Now the field was full of taxiing biplanes, all zigzagging as the pilots tried to see past the airplanes' noses.

Some arrived from Oregon and California, but most came from Washington State. Soon there was a row of more than 20 parked on the ramp, most of them Pitts Specials or Christen Eagle IIs, with an aloof old Great Lakes and a pair of spindly Citabrias punctuating the line. Tomorrow, these airplanes and their pilots would compete to decide the regional champions in four classes of aerobatics.

I could feel something stirring deep inside me. Les and I walked along the line, pausing as he pointed out details. To the casual observer the airplanes were all alike, but he knew the differences. One Pitts' engine was supercharged; some had no starter (to save weight); another concealed a huge 260-horsepower engine under the cowling—almost enough power to hover!

We found Dave Womeldorff working on his Eagle. Dave is chief of design in a heavy-duty military airplane refurbishment program at Boeing, and he and Les work together there when they aren't playing around with terrific little biplanes. Dave looked at me and said, "Hop in."

"Well, I . . . "

Les' grin told me I'd been set up. There was no honorable way out. I put my foot where Dave pointed and stepped into the front seat, humming an old Air Force song: "If you live to be a gray-haired wonder, keep your nose out of the blue. . . . "

"GI, you ready?" Dave yelled from the rear seat. I nodded. The engine's 200 horses awoke with a start, and the propeller blurred. The little airplane rumbled as we taxied out, and in moments we were racing along the concrete. Then the tail lifted, and before I could swallow my gum we were climbing at a steep angle.

Suddenly Dave said, "You've got it." He held up his hands for me to see, and I grasped the stick and placed my feet on the rudder pedals.

It was like nothing I'd ever done before. From the moment of takeoff, it was *flying.* No mushing, no staggering—this airplane was alive. I moved the stick and the world tilted sharply. I banked back the other way—zap! I was delirious. Wings level, the airplane zoomed upward as if it feared the ground. Finally, I reined it in at about 4,500 feet, a good, safe altitude to try some basic aerobatic maneuvers. "It's still your airplane," Dave said. "Have fun."

I did a loop. It felt great, but I pulled only about three Gs. Dave said the loop was too big. I tried another—four Gs this time. I was afraid I'd overtax the airplane, but it whipped cleanly up and over in a tight loop no more than 400 feet across. I'd done loops in fighters before—vast vertical circles taking over a mile of airspace. But then, it takes a lot of room to loop an anvil.

Dave didn't say a word, so I tried a Cuban eight—a figure eight lying on its edge—then a slow roll and a four-point roll.

I'd never tried inverted flying, but it wasn't difficult: I just rolled the airplane over on its back and pushed forward a little on the stick; we purred along, Earth up, sky down. My instincts told me to get right side up again—this was unnatural. Birds don't fly inverted, why oh why should I? I tried to turn while inverted and got everything backwards. I just laughed hysterically.

There was one more thing I wanted to try: a rolling 360-degree turn. It calls for the pilot to make continuous aileron rolls, so the result is a kind of circular corkscrew. I asked Dave to demonstrate part of one. The steps went something like this:

Mix left stick with back stick and top rudder, transition to neutral stick and right rudder, then to forward stick and left aileron and bottom rudder . . . or was it top rudder?

The G forces flowed from positive to zero to negative to zero to positive. I was impressed.

"See? It's easy. Anybody can do it," Dave called up to me.

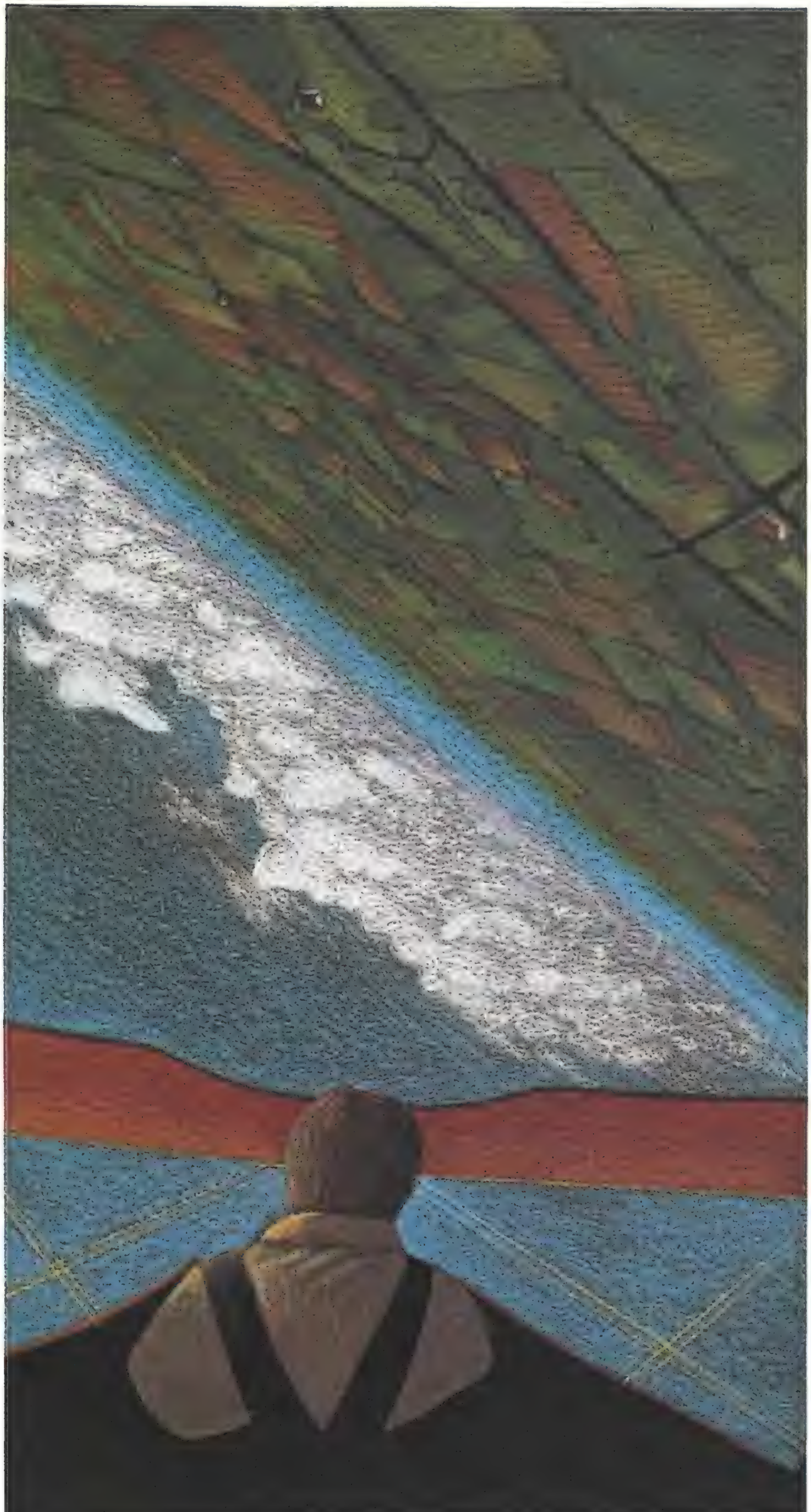
Yeah, sure.

Back on the ground, reluctantly, I felt the fulfillment and gratitude that come from being one of the privileged few who fully savor the sky. I knew then what had been missing from my life.

The next morning, Dave took top honors in the competition's "advanced" category. His rolling 360 was a thing of beauty. As I stood there, a voice at my shoulder muttered, "I hear you'd give a quart of blood to fly a Pitts." It was Herb Clark, owner of a star-spangled, red, white, and blue Pitts Special. I held out my wrist. "I don't charge for fighter pilots," he chuckled.

Off we went. We flew placidly along a nearby canyon, a wondrous water-carved swirl of stressed stratum, ancient and wild. Once clear of the competition area we

Phil Jordan



climbed to a safe practice altitude. I did every maneuver I'd ever learned. Then I asked Herb to show me his routine.

What followed was inspired flying. There was no time to breathe between maneuvers, and there were some I couldn't even name. All the moves were crisp and precise. We were upside-down much of the time, and I experienced my first square loop—a loop with corners on it.

Then I took a turn. I was right in the middle of a very sloppy Cuban eight and had gotten sort of inverted in the recovery when black oil suddenly splattered across the windscreen.

Completely calm, Herb said, "I've got the airplane."

I wasn't sure just what had happened. "Did I break it?" I asked.

Herb laughed. "No way! You can't break a Pitts."

He headed for the airport, called the tower to declare an emergency, and set up a gentle glide. The oil pressure was fluctuating but not falling. I scanned the highway for cars, thinking, *Maybe we could land there if it quits.*

We made it with no difficulty. But a lot of anxious people were there to meet us. The airplane looked terrible: the entire right side of the fuselage was black with oil. Later that afternoon I checked in at the hangar. The airplane was over in a corner, looking as if it were in a hospital emergency room. It squatted there dutifully, engine cowling open for inspection. The culprit: a stuck valve in the system that supplies oil to the engine when the airplane is inverted.

When the competition ended, a quiet young man named Guido Lapore from Vancouver, British Columbia, took top place in the "unlimited" class. He had flown a routine that had us standing and clapping one another on the back. A champion had emerged. But in a way they were all champions—doctors, lawyers, engineers, business people—and I came away feeling like one of them. I was finally an aviator again.

Today I page through *Trade-a-Plane,* window-shopping but knowing I can't afford either an Eagle or a Pitts. But I hear the growl of that engine and feel its heartbeat. I can see the green Earth above my head at the top of an effortless loop, and I can feel the airplane sigh as it stops in midair at the peak of a hammerhead.

I'm back to putting my radio-controlled model through the maneuvers, but it isn't at all like the real thing. My Cuban eights are a little sloppy, and I still can't figure out the rolling 360. But I'm getting better. And the model will have to do until I put a few more dollars together to get that baby-blue Pitts.

—Gene I. Basel

The Meteor Is the Message

Illustrations by Paul Salmon

Billions of times each day, the Earth sweeps up bits of celestial refuse and transforms them into bright orange streaks of fire as they burn through the atmosphere in a split second. They are meteors, or shooting stars. They are the stuff wishes are made of—and the essential medium for a promising system of sending messages.

Meteors, it turns out, reflect radio waves just as mirrors reflect light. And ground stations up to 1,200 miles apart, equipped with sufficiently powerful transmitters, can reach out and touch each other by bouncing signals off the meteors' fiery trails.

Most meteors are no bigger than grains of sand, and they usually strut their stuff in the wee hours. Because of the way the Earth rotates, the United States is on the planet's "leading edge" from midnight to noon and the "trailing edge" from noon to midnight. So just as more bugs strike the nose of an airplane than the tail, more space junk enters the U.S. atmosphere, if you will, after Johnny Carson has signed off.

As a bit of rubble enters the ionosphere at an altitude of 35 to 70 miles, heat generated by friction strips the electrons from the atoms along the meteor's path. This ionization produces a reflective layer of electrically charged particles that can stretch for several hundred miles. Because they block the passage of radio waves, such trails are responsible for the loss of contact with spacecraft commonly experienced during reentry, a nuisance for the incoming crew and mission controllers alike.

But the trails are proving to be an asset for others. For example, the U.S. Department of Agriculture now uses so-called meteor burst communication to collect data from remote weather stations spread across western mountainous regions. As part of a snow telemetry system dubbed SNOTEL, unmanned stations powered by solar energy and batteries are tapped daily for measurements of precipitation, temperature, and accumulated snow.

Far to the north, the Alaskan Meteor Burst Communication System, operated by several federal agencies, provides weather information to remote sites throughout the state. The network also conveys flight statistics from distant airfields and information about the height of waves from buoys anchored in the Gulf of Alaska.

Oil companies use meteor burst commu-

nication for monitoring offshore drilling rigs. Aircraft and ocean liners can relay their positions via meteors, according to recent tests. And researchers are looking into the feasibility of mounting transmitters on icebergs and drifting buoys to warn ships of icy hazards.

In practice, radio operators at master stations broadcast a continuous signal instructing remote stations to send their data. The signal fans out over most of the sky and almost immediately encounters a meteor. The signal bounces down to a remote site, which responds by sending a radio burst skyward. This signal then bounces off the same meteor trail and back to Information Central.

The time required to contact all the stations depends on the network's size—and the season and time of day. In August, the Earth encounters a host of meteors and the wait is but a few seconds. In February, a quieter time in the heavens, the polling may take several minutes.

Communicating via meteors is actually an old idea—scientists experimented with the technique in the 1950s. "But with the advent of satellites, it was simply forgotten," says Donald Sytsma, general manager and co-owner of Meteor Burst Corporation of Kent, Washington.

Two factors have sparked a revival. "From a defense point of view, satellites can be destroyed, whereas meteors provide the basis for an invulnerable system," says Sytsma, whose company manufactures equipment for meteor burst communication. It's not surprising, then, that the Pentagon underwrites most experiments with the systems. Also not surprising: most applications are classified.

"The other factor," he says, "is that recent advances in microprocessors have dramatically cut the price of equipment." Outfitting a master station costs $40,000 to $100,000. Remote stations run about $5,000 to $10,000.

Using meteors does have drawbacks, however. Because they are sporadic and short-lived, so is contact between stations. And radio bursts can carry only a few words' worth of information, which makes voice transmission difficult.

But last July, engineers at GTE Corporation compressed voice signals into short radio bursts and bounced them off meteors flashing across the New England sky. Broadcast from a facility in Westborough, Massachusetts, the signals were picked up near Sebago Lake in Maine, 150 miles away. However, until the technology improves, researchers will have to be satisfied transmitting test signals via space debris, a celestial version of junk mail.

—*Gregory Freiherr*

The Herd Shot Round the World

The roundup would have been right at home in Texas. But the scene was Greenland, an Arctic island north of Canada that is three times the size of the Longhorn State. The "cowboys" were Eskimos and Danes, the herd dogs were huskies, the cattle were musk oxen. And the shaggy animals weren't being driven along dusty trails to Fort Worth, but airlifted to sites just an hour's flight from the North Pole.

The aim of this adventure on ice was to restock musk oxen in northwestern Greenland so that local Eskimos, known as Inuits, could hunt them as they did years ago. The plan: capture 27 calves from a thriving herd in the Sondre Stromfjord region and transport them to new stomping grounds, with the help of the U.S. Air Force and Coast Guard.

Code-named Operation Musk Ox, the airlift represented a goodwill gesture from the United States to Denmark and Greenland (a self-governing member of the Danish Empire), says Lieutenant Colonel C.P. Poore, logistics director at Sondrestrom Airport, where Air Force missions operate side by side with Scandinavian Airlines flights to and from Copenhagen.

Early in July, a team of Danish scientists and Inuits rounded up yearlings and brought them to Sondrestrom. The animals—19 females and eight males, weighing about 250 pounds each—were put into individual crates and prepared for the flight north. The oxen, along with a battery of scientists and members of the Danish press, then waited for a big bird from the south—a C-141 Starlifter from McGuire Air Force Base in New Jersey.

After the hefty crates and a one-ton pallet of fresh hay were loaded into the cavernous airplane, it was off to Thule, two hours away. The oxen were treated to inflight snacks of hay and squirts of oxygen (no word on what the other passengers were served).

The C-141 landed in a light snowfall and heavy winds. Thule, a vital Air Force space command and radar site, then became host to an old-fashioned cattle show. Next came the operation's most critical stage. Pack ice still choked North Star Bay and massive icebergs loomed just past the shoreline, not far from where Admiral Peary's North Pole expedition embarked in 1909. Enter the Coast Guard icebreaker *Northwind.*

Seven oxen were loaded aboard the ship for what was meant to be a brief trip to their new home at Cape Athol, 20 miles to the south. The *Northwind* easily cut through four-foot-thick ice en route. But a surprise snow squall delayed the oxen's helicopter trip to the icy cliffs along the coast.

Despite Arctic brightness throughout the night, the anxious crew had to wait 12 hours before improved weather permitted the final airlift. Soon, a bright orange Coast Guard helicopter nicknamed Ox Cart ferried the crated bovines to the cliffs and their stark scenery of snow, icebergs, and pack ice.

Over the next few days, the *Northwind* sowed another six oxen at McCormick Fjord and 14 at Inglefield Land.

"The return of the musk oxen to this region marks the first time since 1860 that the animals are among us," says Ussarquak Qujaukitsoq, an Inuit hunter and member of Greenland's parliament. "My people have expressed their happiness that the expedition was successful and that musk oxen are not just a part of our legends but part of our lives again."

This wasn't the first restocking operation, although it was the first by air. "Twenty years ago, we were so successful at Sondrestrom that a herd of 1,100 oxen

now roams the fjord," says Christian Vibe, a zoologist from Copenhagen who has spent 50 years in Greenland. "We started with 27 there, too." Vibe estimates that in 12 years, musk oxen will be plentiful in the far north and the Inuits can hunt them again.

Throughout the winter, scientists will be monitoring the health of the herd, which will face a survival test at temperatures averaging -15° F. More musk oxen will be flown in next year if necessary.

—John Metzler

Space Architecture: Think or Swim

Thousands of miles above Earth, a computer floats in a water-filled glass sphere that was manufactured in space. A tubular laboratory encircles the 250-foot-wide sphere like a planetary ring, and inside scientists are busily studying holographic images that the computer churns out.

The computer, built from large and

Peter Bollinger

nearly perfect crystals that can be grown under weightless conditions, does not respond to keyboard or voice commands from the scientists. It responds to ultrasonic waves generated by dolphins, who live in the shimmering sphere.

This twenty-first century scenario is the product of Doug Michels, an architect in Washington, D.C. He came up with the idea for Project Bluestar, which he envisions as "the first think tank in space," during a recent fellowship at Harvard University's Graduate School of Design. "Scientists would live in nearby space cities and fly to work," he says. Their goal: communicate with and learn from the dolphins.

Why dolphins? "They are intelligent, and there's a human-dolphin affinity that goes back to the time of Plato," Michels says. "Dolphins are also at home in an environment that's similar to space. Their brains are programmed to a three-dimensional world, while ours are only programmed for 2-D. But most importantly, their sonar is so advanced that it's more sophisticated than anything the Navy's got."

Michels recently presented his ideas at Washington's Octagon Museum in an exhibition entitled "Ideas Above Earth: Space Architecture." "The space frontier is a symbol of the unlimited potential of the mind," he wrote in the exhibit's introduction. "Instinctively, we realize space is a new world so rich in possibilities for human advancement that we can begin to perceive a new phase of civilization being born."

One aspect of this new age is the emergence of space architecture: "Just as previous historical periods have been articulated by their architectural styles—Greek, Roman, Gothic, Modern—so too will space architecture define our epoch," he noted. The most dramatic departure from terrestrial architecture will undoubtedly be the absence of floors, ceilings, and walls. Architects will create radically innovative environments for living in the round with no up-down references.

Michels has discussed his ideas with designers in the National Aeronautics and Space Administration's human factors laboratory. Current space station plans call for traditional floors and ceilings because astronauts asked for them. But that doesn't faze Michels—he's sure that once people have spent enough time in space to become comfortable, they will discard old notions about how homes and workplaces should look.

Indeed, Michels is even convinced that space inhabitants will eventually think and behave differently than their terrestrial neighbors. After all, he points out, "weightlessness has a profound effect on the behavior of materials. Maybe the brain will also work differently in space. Maybe we'll be able to use more than the ten percent of our brain that we now use." Or maybe not—but Michels says there's only one way to find out.

Although Michels has drawn up a stack of blueprints, Project Bluestar isn't quite ready for construction. For one thing, crystal-based computers haven't hit the market yet. "Bluestar is based on today's technology but in an advanced state," he explains. "These ideas are just conceptualizations—we're architects, not scientists."

Michels has already seen some of his "conceptualizations" become reality. Several years ago he designed a futuristic house in Houston, Texas, based on curves and spherical structures instead of traditional lines and cubes. He describes the house as one that "George Jetson could feel at home in." Fortunately, its occupants seem to feel at home there, too.

So perhaps some evening decades from now, you'll look up and see a glint of sunlight reflecting off an orbiting home for dolphins. Or you may be looking down at Earth, wondering how you ever lived in a linear, gravity-burdened world for so long.

—Katie Janssen

It's Always in the Last Place You Look

In the early 1940s, when the outcome of World War II was anybody's guess, the U.S. War Department offered pilot training to civilians to ensure a ready pool of fliers for active duty. Nearly 500,000 people learned to fly during the four years of the Civilian Pilot Training Program.

Few trainees were ever called upon to use their skills in the war—indeed, many dropped out before finishing the program because the government required graduates to serve in the military. Some people eventually used their experience to help fulfill requirements for a civilian pilot's license. Others gave up flying, except as an item for conversation and scrapbooks.

But more than 100,000 trainees were for years unable to prove, whether for official use or simply bragging rights, that they had participated in the program. Until Bert LaCroix of the Federal Aviation Administration struck gold—or rather paperwork.

In late 1985 LaCroix, manager of FAA's paperwork management branch, was making a periodic review of old records to determine what should be saved or destroyed. He came across an item suggesting where to look for the microfilms of training records, which had been missing since the early 1960s, when the FAA's Airmen and Aircraft Registry division moved from Washington, D.C., to Oklahoma City.

Some of the agency's baggage had apparently been left behind, says division manager Earl Mahoney. The records ended up being stored by the General Services Administration in Maryland. Cartons containing 138 reels of microfilm were delivered to Mahoney's group in Oklahoma City early in 1986. He estimates that each reel contains records for perhaps 1,000 civilians—"though there could be up to 200,000 trainees accounted for, since I've only looked at a half dozen reels so far."

Mahoney is elated over the find. "There was a chunk missing from the pie," he says.

"We've had lots of inquiries but we had no idea where the records were. We couldn't even tell people who they should write to."

The paper chase ended just in time. When LaCroix first spotted evidence of the records, they were candidates for destruction by the National Archives. But working with archivists, he managed to save them.

Mahoney says the microfilm is in good condition and the trainees are indexed alphabetically, which should make for easier searches. A quick scan for familiar names has already turned up Engen, Donald D., the current FAA administrator.

The records will be permanently stored at the registry division—the official record keeper for all civilian aircraft in the United States (about 300,000) and all civil pilots, instructors, and mechanics (about 2.9 million). "We usually get about six to 12 inquiries a year on Civilian Pilot Training records," Mahoney says, "but interest always peaks after a TV show on Amelia Earhart or Lindbergh or any famous flier. People want to find out if Uncle Joe really did fly an airplane in 1943. Now we'll be able to tell them."

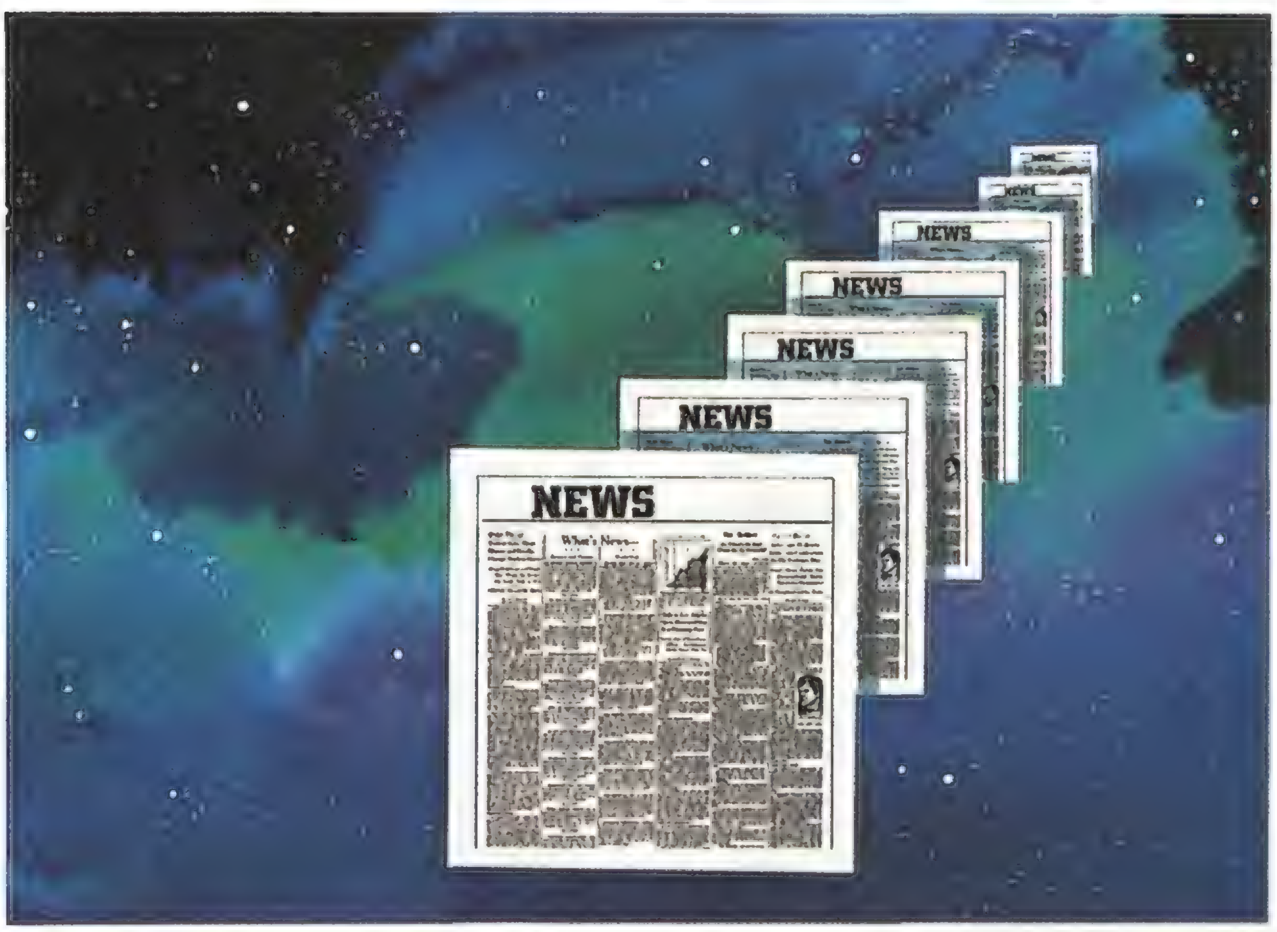
—Reginald Stuart

Tonight's Asteroids Today

An astronomical tradition ended recently: Jay Gunter stopped publishing *Tonight's Asteroids*, the only newsletter for amateur asteroid watchers. But all is not lost. The bimonthly astroletter has been handed over to astronomer Joe Flowers, who will continue the service of supplying a lifeline for asteroid hunters—for the price of a stamped envelope.

Tonight's Asteroids—*T.A.* to its fans—is devoted to the more than 3,000 chunks of rock known as minor planets. They were created at the birth of the solar system and now orbit the sun in a belt 100 million miles wide between Mars and Jupiter.

While the newsletter calls itself "a project in amateur astronomy," professionals aren't excluded. Indeed, many on-the-job astronomers are regular readers, including Brian Marsden, director of the Minor Planet Center at the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, and Eleanor Helin, a research scientist at the Jet Propulsion Laboratory in Pasadena, California, who is involved in asteroid research.



The 76-year-old Gunter, formerly a pathologist at Watts Hospital in Durham, North Carolina, started the newsletter in 1971. "Amateurs didn't pay any attention to asteroids then because they didn't know where or how to look for them," he explains. "They just didn't have the information. All I did was take the trouble to get it and pass it on."

Even though asteroid watching ranks as one of the loneliest of all astronomical endeavors—Gunter estimates that only about two percent of amateurs are asteroid hunters—his enthusiasm spread through the amateur community. So did his newsletter—today *T.A.* has more than 700 subscribers worldwide.

The new editor, who teaches astronomy at Wilson County Technical College near Durham, discovered his calling early. "When I was six we lived out in the country," Flowers says, "and my father would take me out in the evening and show me the first generation of satellites overhead." Next came an insatiable appetite for astronomy books.

What's the appeal of asteroids? "The constellations appear in the same patterns,

year after year," he says. "With asteroids, especially the closer ones—less than 50 million miles away—you can watch their steady motion, as if they are actually moving among the stars."

Knowing a good thing when he sees it, Flowers doesn't plan many changes for the newsletter: "The only differences are that I won't be traveling to astronomy conferences as often as Dr. Gunter did—mainly because I have a five-year-old and a two-year-old—and I will be doing more observing than he was able to do."

"It was great fun running the newsletter, but the time has come to give it up," Gunter says. "I have other obligations and it just takes too much time to get it out—writing doesn't come easy to me. I never thought anyone would take over the project, so I was really surprised when Joe offered to do it. I feel confident that he will make a success of it."

Flowers' first effort, an eight-page November/December issue, features the usual fare. There are reports on individual asteroids, including their locations, their discoverers, and the origins of their names. For example, asteroid 2476 Andersen is named for Hans Christian Andersen, the Danish fairy tale writer, and 2309 Mr. Spock for a tabby cat owned by the asteroid's discoverer. Fan mail is next, giving encouragement—many people write about finding their first asteroid after reading *T.A.*—and trading news on the latest sightings. Book reviews summarize the latest astroliterature by professionals and amateurs.

Flowers volunteered to take over the newsletter because he, like Gunter, feels that amateur asteroid hunters provide a great service. "Amateur astronomers do most of the observing today," he says. "Professionals are often tied up with programs and paperwork, and it's the amateur who goes out in the backyard with a telescope after dinner and does the observing, often spending the entire year watching the same asteroid.

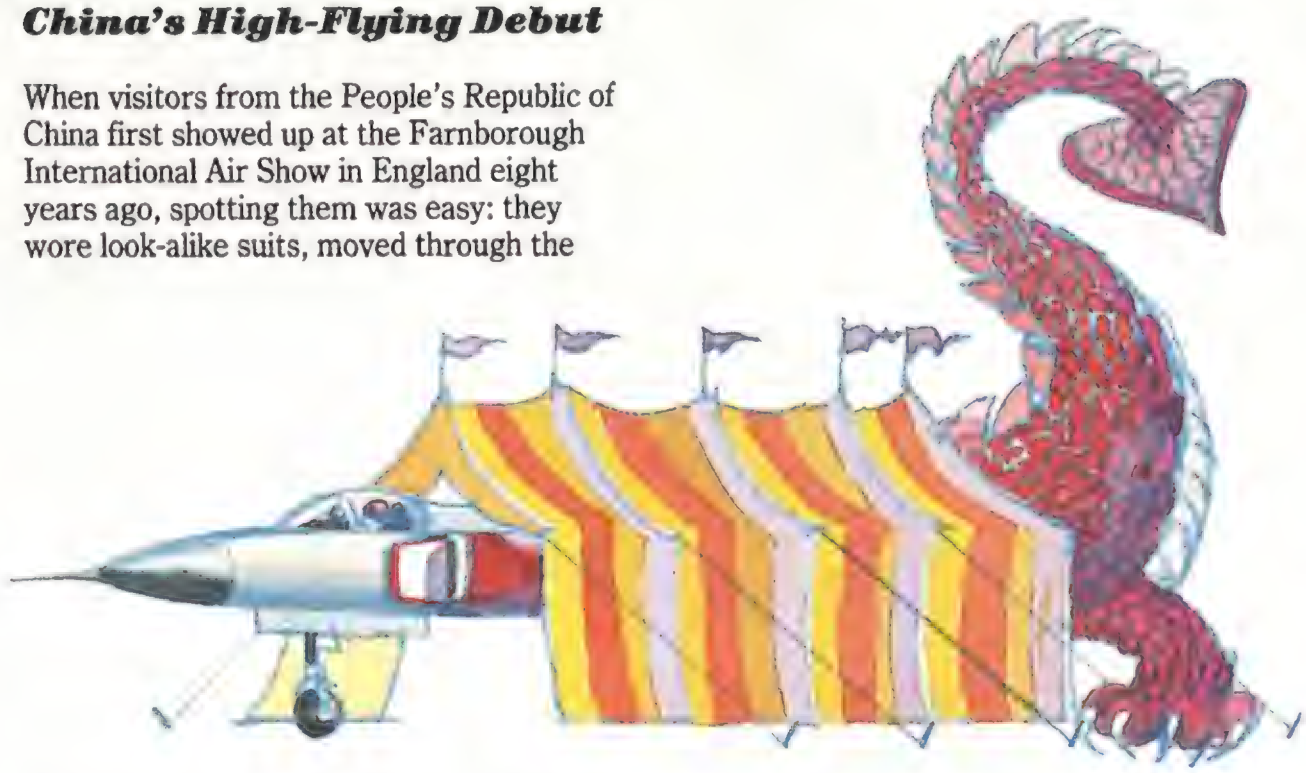
"Also, there are far more asteroids than there are professional astronomers to keep track of them," Flowers notes. "It's one area in which amateurs can really make an important contribution to science."

Although Jay Gunter has passed the baton, *T.A.* hasn't left his thoughts. "I'm proud of the little group who through my efforts have developed a deep interest in minor planet studies and are making significant contributions to knowledge in this field," he wrote in his final issue. A perfect example is Rick Binzel of Texas, who first subscribed at age 14 in 1972—he is now editor of *The Minor Planet Bulletin.*

—Patricia Barnes-Svarney

China's High-Flying Debut

When visitors from the People's Republic of China first showed up at the Farnborough International Air Show in England eight years ago, spotting them was easy: they wore look-alike suits, moved through the exhibits in clusters, and usually sported plastic shopping bags.



At each display they would pick up flashy sales brochures touting aviation wares. Whenever someone tried to start a conversation, they smiled diffidently and moved on. The visitors were clearly window-shopping, gathering as much promotional literature as they could stuff in their bags.

At the latest show, in September 1986, the Chinese were still smiling—but no longer timid. They radiated confidence, liberally sprinkling conversations with French and English marketing terms. They wore well-cut suits in a variety of colors and designs. And instead of collecting brochures, they handed them out by the sheaf.

The Chinese aerospace industry was selling at Farnborough, and selling hard.

It was the country's first active appearance on the trade show circuit. Several companies, under the umbrella of the government's China Promotion Limited, rented major exhibit space and booked a plush reception chalet for business discussions and entertainment. China's presence at the Farnborough show, a biennial exposition of military and commercial aviation and aerospace hardware that draws hundreds of companies, forecasts an aggressive future in promoting its aviation and space industries in the West.

The Chinese booths in the main exhibit hall were nearly three times larger than those of U.S. giant McDonnell Douglas, and they outshone other Farnborough veterans as well. The fact sheets and other promotional material passed out by salespeople from China National Aero-Technology Import and Export Corporation and China National Electronics could have been produced by the marketing squads at Lockheed, Northrop, or General Dynamics.

The multilingual brochures were filled with all the buzzwords. From an electronics brochure: "In accordance with our motto 'Customer First,' our corporation can provide you . . . ." From another, promoting an upcoming trade show in Beijing: "Explore business opportunities with the Chinese defense industry . . . ."

The products offered ranged from zinc-silver aircraft batteries and hand-held radios to long-range radar systems, missiles, and supersonic fighter aircraft. Their premier offering, the Mach 2.2 F-8 II, an airplane that blends Soviet MiG-21 and MiG-23 designs, was on display as a one-tenth scale model. Sales representatives announced that they were looking for Western partners for the development of avionics and navigation equipment and possibly of the engines, and reported that negotiations were under way with Grumman and Northrop, among others. Other models included the F-7 Airguard, an enhanced Soviet MiG-21 with an electronics package from Great Britain, and the A-5 fighter, which features a new navigation-and-attack system being developed by the Chinese and Italy's Aeritalia.

When bona fide business prospects appeared, the Chinese followed through like veterans. The courtships progressed in the exhibit area and in the elegant chalet on the flight line.

Representatives were close-mouthed about actual orders. But they readily admitted that they are making a coordinated sales effort in the West. They are also seeking Western partners to help make the leaps in technology needed to excel in the world marketplace. When that happens, the U.S. aerospace industry will face even tougher competition for business.

—F. Clifton Berry, Jr.

Cops and Rotors

The legends of airborne law enforcement are growing. There's the time a Pennsylvania state police pilot slapped a murder suspect to the ground with the skids of his JetRanger helicopter and kept him pinned until officers on foot arrived with handcuffs. And the time Los Angeles firefighters used their Bell 47G helicopter to rescue two elderly women, up to their shoulders in mud and water, from the patio of their house just before it was inundated by rushing torrents from a broken dam.

At the Airborne Law Enforcement Association's "Pig Pickin' " in Arlington, Texas, last August, police, fire department, and drug enforcement aviators swapped tales of what they've been up to with their machines. The picnic, featuring roast pig, free-flowing beer, and a German "oompah" band, highlights the association's annual convention. But when 700 law enforcement officers from all over the country gathered for the 17th convention, it was clear just how serious—and how fast—airborne police work is growing.

In 1970, there were only 61 civil agencies in the United States operating aircraft. Today there are 335 police, fire, and drug enforcement agencies flying more than 2,000 aircraft. The workhorse of this air force is the helicopter—approximately nine percent of the world's helicopter activity is devoted to law enforcement.

Far more than a magic carpet for traffic reporters, the helicopter is an excellent crime-fighting weapon. Standard equipment on many police helicopters is a 30-million-candlepower floodlight, usually suspended from the chin, that is so bright its presence at the scene of a night crime is often enough to flush out suspects.

Larry Mize of the Baltimore Helicopter Unit recalls surprising a burglar cutting a hole in the roof of a shopping center one summer night. "His eyes were as big as saucers," Mize says. "He started running until he went right off the edge of the roof, and his feet were still moving when he hit the ground. The light was driving him crazy—he ended up running around in circles in the backyard of a house. Finally, in desperation, he dove under the porch and hid until the patrol guys pulled him out." Blinded by the light, indeed.

Airborne police are finding that high technology is reaching increasingly into their skies. For example, forward-looking infrared (FLIR) can be used in conjunction with the powerful lights. FLIR, developed for the military, detects objects at night by their heat emission.

A FLIR-equipped helicopter arriving at the scene of a crime can begin its search by pointing the floodlight at a random site. Suspects sometimes respond to the errant light by moving, thus revealing their position to the FLIR. Once movement is detected, the helicopter crew can advise units below where to make the capture.

According to its manufacturers, FLIR can also "see" concentrations of ether at ground level. Since ether is often used in manufacturing illicit drugs, detection from the air would assist in putting illegal laboratories out of commission.

Even a plain-vanilla helicopter expands the capabilities of a police department. Used in pursuit, it can precede ground units involved in a chase, clearing out intersections and reducing the potential for accidents—and the department's potential liability for them.

Airborne units often foster jealousy among ground-based patrols, and avoiding dissension was one of the topics on the seminar schedule. Pilots stress that their work would be useless without ground patrols—few arrests could be made without someone to put on the handcuffs.

There is little doubt that the helicopter's role in police work and firefighting will continue to expand. Some industry analysts predict that the worldwide market for law enforcement helicopters will more than double in the next decade.

Judging from this year's convention, that is also the belief of manufacturers, who were there in force with their latest and shiniest models. At more than a quarter of a million dollars each, they represent a substantial investment—but as Hollywood's *Blue Thunder* proved to moviegoers, it's quality, not quantity, that counts.

—*Byron Harris*

General Entertainment

Comedienne Phyllis Diller decided to skip the old-age jokes as she left the shade of an F-14 Navy fighter and burst onto the stage, lavender hair flying, for her 23rd appearance on a Bob Hope military show. At age 69, she was far too young to garner any sympathy from the guest of honor for her wrinkles.

It was a sentimental reunion as well as a moving salute when Hope and a slew of celebrities gathered at Miramar Naval Air Station in San Diego early in June to film an old-fashioned road show honoring the 90th birthday of General James H. Doolittle. Miramar is where Doolittle, former stuntman, aviation pioneer, World War II pilot, Medal of Honor recipient, and the only ex-soldier since George Washington to earn four stars, learned to fly.

The general's birthday is actually December 14, but to paraphrase James Russell Lowell in Hollywood terms, what is so rare as a day in June when everybody can make it? And compounding chronological complexities, the show was aired by a cable television network in August.

In a rapid patter of one-liners, Hope recalled entertaining Doolittle for the first time during a United Services Organization (USO) tour of North Africa in 1943. "He was always good to me," Hope deadpanned. "He made sure they always had my blood type around, even if he had to kill the chicken himself."

Jimmy Stewart, who flew B-24 Liberator bombers under Doolittle's command, drew

a standing ovation from the audience of 5,000 Marines, sailors, and their families when he reminded them that World War II was fought "by brave, courageous heroes, and that bravery, courage, and strength came from the top. All of us were inspired by his leadership. . . . We had confidence in a man who knew aviation as well as he did."

A small man with a fringe of white hair, Doolittle sat in front of the stage, surrounded by many of his Tokyo Raiders and fellow members of the American Fighter Aces Association (pilots who have shot down at least five enemy aircraft) celebrating the group's 25th anniversary. His wife of 69 years—Josephine, or "Mama Jo"—and other family members were also on hand. With obvious delight, he took the microphone just long enough to say "Thanks" and remind the audience that "the Navy and the Marines represent the best of all."

A carnival mood prevailed as parents with lawn chairs, coolers, and hordes of children pressed in behind the VIP seating in the parking lot. Off to one side were booths selling corn dogs, lemonade, beer, and—because it was, after all, a California crowd—wine coolers. Hundreds of Marine recruits in camouflage uniforms were bused in and seated for the benefit of the cameras in orderly rows on the hot pavement. Drill instructors ordered them up on their feet to stretch periodically during the four-hour event, and barked at them to fulfill the producer's request for greater volume on the "Battle Hymn of the Republic."

Most in attendance were far too young to remember the historic day, a few months after the Japanese attack on Pearl Harbor, when Doolittle and the Tokyo Raiders proved that America's military power was still intact. On April 18, 1942, Lieutenant Colonel Doolittle took off from the carrier *Hornet* leading a squadron of Army Air Corps B-25s on a one-way flight. They bombed Tokyo in broad daylight, then struggled to the Chinese mainland before their fuel ran out.

Up on the flag-draped stage, flanked by an F-14 and a Grumman E-2C Hawkeye, Glen Campbell told country-style jokes to break the monotony between acts as the production crew scrambled for camera angles and cue cards. The audience applauded when the cameras finally rolled and Campbell introduced the Lennon Sisters—who weren't there. They were to be taped elsewhere and added to the television show, as were birthday greetings from President Reagan. In person were singers Shirley Jones, Jack Jones, Hope's wife Dolores, and comedian Don Knotts. Rich Little ran through his day-in-the-life-of-the-president routine and his Kermit the Frog rendition of "We Are the World."

Audrey Landers, formerly of TV's "Dallas," carried on the Hope tradition when, minimally clad in sequins, she danced with a sailor, a Marine, and an admiral as she sang "Let's Hear It for the Boy." To the delight of the troops, the producer called for another take after Rear Admiral A.L. Newman, commander of the Fighter Airborne Early Warning Wing, U.S. Pacific, failed to "shake it" with enough enthusiasm ("Remember, rhythm, Admiral, rhythm!").

Changing times among the troops were brought to light when Hope drew groans with jokes about "lady pilots": "They have curtains in the cockpit and lace on the afterburners." He fared better with his usual targets: politicians, golf, and Dean Martin.

A rousing finale of "America the Beautiful" sent the Doolittles, the Aces, the Raiders, and the stars off to a dinner dance and further celebrations.

Jimmy Stewart best summed up the tribute when he noted, "One of America's strengths is that we always seem to produce the right leaders when we need them." Jimmy Doolittle was there when we needed him for more than half a century. Happy 90th, general.

—*Yvonne Baskin*

Update

The National Pilot Training program proposed by the Aircraft Owners and Pilots Association ("The Great American Pilot Shortage," October/November) has been withdrawn. AOPA president John L. Baker, citing member dissatisfaction with the flight-training scholarship idea, says the association will search for other methods to encourage people to become pilots.

Voyager's around-the-world flight planned for late September ("Voyager," October/November) was postponed after vibration in a propeller during a short test flight led to the loss of a blade and engine damage. However, pilots Dick Rutan and Jeana Yeager must soon be on their way with a revamped engine and a new propeller or they will be grounded until spring. The "weather window" for takeoff closes November 30, when Southern California desert winds start to pick up, and will not open again until the end of May.

The wreckage of the Navy dirigible *Akron* ("Cathedrals of the Sky," April/May) was discovered early in August two miles from the crash site, off the coast of New Jersey, by a team from the National Underwater and Marine Agency of Port Jefferson Station, Long Island. "There are pieces of the frame ranging from 30 to 120 feet that are corroded, encrusted with sea life, and

spread over a debris field about 700 feet long," says Zeff Loria, project director. The agency, headed by Clive Cussler, author of *Raise the Titanic!* plans to turn over to the Navy any material recovered in a second expedition next spring.

Wind shear research ("The Might of the Microburst," August/September) has revealed that columns of torrential rain contribute to wind shear, and that the radar echo from such a downpour sometimes weakens before the microburst hits the ground, giving a false impression that no danger exists. Tetsuya Fujita, microburst research pioneer, made the discovery while reviewing test data from Alabama studies, and recommends that pilots should avoid areas of heavy rain and should not be misled by weakened radar echoes.

The National Aerospace Plane program ("Space Plane," August/September) has received funding for the first year of technology development—a budget of $167 million for fiscal year 1987 earmarked by a congressional resolution for continuing appropriations. The Department of Defense will receive $110 million and NASA $57 million ($40 million for technology development and $17 million for wind tunnel testing). The House Appropriations Committee had recommended deleting Navy and Air Force funding but ultimately dropped the proposal in conference deliberations.

The V-22 Osprey tilt-rotor aircraft ("Soundings," October/November) will soon be marketed to European and Australian military agencies, though international purchases are not foreseen until the late 1990s. Program officials at Bell and Boeing, bolstered by a U.S. Navy decision to order an additional 300 Ospreys and an increase in the Army's order, say that "Osprey supporters are beginning to come out of the woodwork."

General aviation manufacturing "has fallen into its most severe recession in history and is clearly a troubled industry," according to a Commerce Department study released late in September ("Hard Times in Hangar Town," April/May). Confirming what has been common knowledge for years, the report finds among the most serious problems "growing foreign competition, declining number of active pilots, increasing prices, product liability, and proposed tax reform." Cessna Aircraft Company, which ceased production of all piston aircraft through the 1987 model year, laid off 700 employees in October in addition to the 900 released in May.

—*Patricia Trenner*

Home Is Where the Hangar Is

I had just taken a job as office manager for an aircraft sales and maintenance company at a small New England airport. Part of the salary was a studio apartment on the upper floor of the hangar. It would save rent money, but could take its toll in other ways—like never being able to call in sick. "If you're starting one new thing," I said to myself, "why not another? Like a journal."

November Wrote to a friend extolling the beauty of the night: "Absolute silence, save the soft drone of engines during final approach and the singular whistling produced by a descending Piper Cherokee. Picture window overlooks the runway intersection, where a rectangle of white guides blinking UFOs to Earth. Cobalt-blue taxiway lights sparkle like electric cornflowers." Friend wrote back: "Had to take an antacid after reading your letter. When are you going to get a *real* job?"

February At any small airport, regardless of the time of day or meteorological conditions, it's a safe bet that a student in a Cessna trainer is practicing touch-and-go landings. This single-mindedness persists in the face of howling gales and winter white-outs. Eastern Airlines may have canceled its shuttle flights and the Air Force sheltered its B-52s in their hangars, but outside my window a 20-year-old Cessna will be snarling around the traffic pattern, getting tossed like a dinghy in a force-nine sea.

July The morning and evening hangar rituals have come to resemble those of a farm: at sunrise, the barn doors are opened, the airplanes set out to graze. At sunset, they are herded back into the hangar by shepherds in oil-spattered overalls and baseball caps. Considered starting a mural depicting this aviation ranch, with cattle wearing navigation antennas from horns to tail and taxiing around the north forty, but got too silly to put pencil to paper.

This rampant inanity has reached a new low: I think I hear airplanes in the hangar flying in their sleep, and am sometimes confronted with a windshield and propeller peering inquisitively through my window.

September As the major league baseball season draws to a close, ours begins. About 20 airport people—a particularly scruffy bunch—have agreed to play softball under the control tower, with no particular regularity. At the opening game, both teams wore T-shirts bearing the name The Beaufort, Georgia, Swomprats, which led to much confusion and up to three runners on one base. Play halted each time an airplane landed to allow for a group critique, which meant we played only five innings before the beer ran out and the mosquitos arrived. Not much talk of a winning season for either team.

December One of our customers has taken to working on his airplane, which is parked directly under my window, at twelve o'clock sharp every night. The problem seems to be the engine, which means he has to rev it repeatedly at high RPM between tinkerings. Nothing carries noise so well as a clear winter night and a large pane of glass for reverberation. It's like trying to sleep during the Berlin Airlift.

April I hear turboprops outside my open window—can spring be far behind? Most New Englanders regard the peeping of tree frogs as a seasonal harbinger, but at the airport they are drowned out by engines. Hark! Hark! A Beechcraft commuter!

May Airport Security stopped by one evening to point out a herd of deer at the runway intersection. During deer season, the tower routinely issues "Go around" instructions to landing aircraft when deer are grazing, and then has Security scare them off the runway with a truck.

Susan Davis

In fact, there is much wildlife here—snapping turtles, crows the size of mopeds, and large worms on the hangar floor after a good rain, which the mechanics try to convince me are actually small snakes. I only fell for it once, and that was at a distance. We also have a pair of Canada geese bold enough to eat out of my hand. Their flapping and honking intimidate some people: the other morning, I stepped outside the hangar to find the company's new mechanic "treed" on the fuel truck by two hungry, vociferous honkers.

August Now that every airplane owner within five miles knows I live here, rumor has it that the dealership is a 24-hour operation. One fine Saturday morning I was awakened at six o'clock by a customer who had neglected to ask us to leave his airplane on the ramp overnight. He stood under my window and bellowed his plight until I clumped downstairs and opened the hangar door. A coworker suggested I take the intruder's fuel bill to his house at six o'clock the next Saturday morning and demand that he come out and pay it *right now.* I think, however, my bathrobe and hiking boots scared him off for a while.

September Hangar life is starting to wear thin. Every weekend morning it sounds as if the Giant Pack Rats of Sumatra are scurrying about in my basement, all looking for parts for 1957 wood-wing Mooneys.

October Found a small apartment a mile away, a more bucolic setting where the loudest noise will come from an organ owned by a neighbor partial to the theme from "M*A*S*H." I move in three weeks.

November My last night at the hangar. Carl Sagan informed me via the "Cosmos" television series that winds on Mars reach half the speed of sound. And you can bet that during peak gusts, there will be a student in a Cessna doing touch-and-gos.

—Patricia Trenner

Anniversaries and Events

1785
January 7 The first aerial crossing of the English Channel, from Dover to Calais, is made by ballooning's first "professional," Jean-Pierre Blanchard, and Dr. John Jeffries, a Boston-born physician. Jeffries financed the flight, but Blanchard tried to garner the glory for himself by lining his vest with lead so that at weigh-in time, it would appear that there was no room for an assistant. As it turned out, all ballast, equipment, and most of the aeronauts' clothing, including trousers, were tossed overboard en route to avoid a premature splashdown.

1903
December 17 A coin toss at Kill Devil Hill determines that Orville Wright will make the world's first powered, manned, heavier-than-air flight, 12 seconds in duration, in the Wright *Flyer*. Wilbur made the most successful of the day's four flights, covering 852 feet in 59 seconds. The airplane was moved to the Science Museum in London in 1928 and spent World War II safely stored in the London subway. On the 45th anniversary of Orville's flight, the *Flyer* was returned to the United States and hung in the Smithsonian, where it resides today.

1910
December 10 During a taxiing test, Rumanian aircraft designer Henri Coanda inadvertently "hops" the first jet aircraft, powered by a 50-horsepower piston engine driving a centrifugal air compressor. In the inventor's words: "I had no intention of flying that day . . . I was concentrating on adjusting the gasoline flow and did not realize the aircraft was gaining speed. Then I looked up and saw the walls of Paris approaching rapidly. There was no time to turn around—I decided to try to fly. Unfortunately, I had no experience in flying." The aircraft was destroyed in short order, but not so its unflappable pilot, who went on to create military aircraft (with reciprocating engines), a bombsight-and-launch device, and an airborne gunnery system.

Chattanooga Bakery Inc.

The Moon Pie celebrates 70 years as a Southern classic.

1914
January 1 The first scheduled airline service via airplane—the St. Petersburg-Tampa Airboat Line—is inaugurated by Anthony Jannus, with a Benoist Type XIV flying boat based at Florida's Tampa Bay. A. C. Phiel, a former mayor of St. Petersburg, paid $400 for the privilege of being the first passenger on the flight from St. Petersburg to Tampa; subsequent passengers paid the standard fare of $5 for the 30-minute ride.

1917
January 1 The Southern classic known as the Moon Pie is trademarked in Chattanooga, Tennessee. A salesman had suggested to the owner of the Chattanooga Bakery that he create a snack composed of two cookies sandwiching a marshmallow filling and coated with chocolate icing. "And it's got to be as big as the moon," the visionary added.

According to one social scientist, today the Moon Pie "is more than a snack. It is a cultural artifact." Ron Dickson notes in the

Henri Coanda's 1910 jet biplane was far ahead of its time—and its pilot.

NASM

Great American Moon Pie Handbook the many uses for the snack, such as using the filling to patch a leak in a bicycle inner tube. "Try that with a pack of cheese crackers and see how far you get," Dickson says.

Today the Chattanooga Bakery cranks out more than 300,000 Moon Pies—its sole product—daily, says Sam H. Campbell IV, the grandson of the bakery's founder. A Moon Pie is traditionally accompanied by an RC Cola for full gustatory enjoyment.

1935
December 27 The 23rd Bombardment Squadron of the U.S. Army Air Corps bombs Hilo, Hawaii. The target was not the city but rather the flow of lava from Mauna Loa. Twenty 500-pound bombs scored direct hits, and the lava, which had been advancing toward Hilo at a rate of one mile a day, slowed and stopped within one week.

1941
December 1 The Civil Air Patrol is formed to back up the military. "The government didn't have enough aircraft to whistle Dixie if we were attacked," said an early CAP backer. During World War II, CAP pilots searched for enemy radio stations, monitored border crossings, and patrolled the East Coast. After Germany surrendered, an officer was asked why the U-boats had stopped their attacks. "It was those damned little red and yellow airplanes," he replied.

Associated Press

Franklin Roosevelt takes a giant step for the presidency aboard a flying boat.

1943
January 14–23 Franklin Delano Roosevelt is the first president to fly while in office; he takes Boeing's *Dixie Clipper*, a B-314 flying boat (see page 92). Roosevelt flew from Miami to the Casablanca conference, a 5,000-mile trip during which he "acted like a 16-year-old," according to an aide, "for he has done no flying since he became President."

1949
January 25 The Air Force adopts blue uniforms to stimulate morale and help in recruiting. Seven top designers had submitted uniforms in colors ranging from light gray to Brunswick green to sapphire blue. The switch from Army olive drab was not immediately successful—enlisted men initially complained of being mistaken for bus drivers. The following year, the Air Force substituted the term "airman" for "soldier," and Army airfields became Air Force bases.

1956
December 4 The Army Signal Corps announces that it will sell its homing pigeons, the ranks of which served their country by carrying messages, maps, and films during times of conflict since 1878.

1958
January 31 The United States launches *Explorer 1*, its first successful satellite, which contained a device designed by James Van Allen to measure radiation levels in space. Scientists feared that the instruments had spun off the scale, so high were the readings. After a fruitless search to discover a malfunction, they realized the readings were indeed correct: saturation levels had been surpassed. They began mapping what came to be known as the Van Allen belts, two regions of radiation beginning at 400 miles outside the Earth's atmosphere and extending for 40,000 miles.

1958
December 19 A military communications experiment called Project SCORE (Signal Communication by Orbiting Relay Equipment) puts the upper stage of an Atlas missile into orbit, and a transmitter and tape recording aboard allows President Dwight D. Eisenhower to make the first U.S. voice-relay broadcast from space. His Christmas message: "To all mankind, America's wish for peace on Earth and goodwill toward men everywhere."

1962
December 31 The Navy disposes of its last airship and abandons the use of lighter-than-air craft—but not wholeheartedly: attempts have been made to raise a blimp-shaped Phoenix from the ashes ever since. The latest effort calls for an evaluation of a development model to be used primarily for airborne early-warning missions. Goodyear, which has been building blimps for 75 years, has proposed an updated version of the ZPG 3-Ws built in the 1950s, twice the size of the current advertising blimps. "We're sticking with the tried and true," says a company spokesman. The alliances of Westinghouse-Airship Industries and Boeing-Wren Skyships are also vying for a contract.

1967
January 27 The first disaster of the U.S. space program occurs when fire breaks out in the *Apollo 1* capsule during a routine training session on the launch pad, killing Virgil Grissom, Edward White, and Roger Chaffee, who were scheduled to make the first Apollo flight on February 21.

1969
January 14, 15 The Soviet *Soyuz 4* and *Soyuz 5* spacecraft are launched, which accomplish the first manned-spacecraft docking and crew exchange in orbit.

1972
December 7–19 Apollo 17, the last lunar mission, ends the program with a 75-hour stay on the moon, the longest in the series of explorations, and the return of almost 250 pounds of lunar samples.

1985
January 28 The second disaster in the U.S. space program occurs when NASA shuttle flight 51-L *Challenger* and all seven of the crew are lost in an explosion 71 seconds after liftoff. Today, the families of the crew are working toward establishing the Challenger Center for Space Science Education, where "people from all over the world can come for hands-on experience in space science," says June Scobee, widow of *Challenger*'s commander. "To take no risk is the greatest risk. The best way to honor the crew is to honor their dreams."

Challenger Center

CHALLENGER
CENTER

Events

Through December 7
"Twenty-five Years of Manned Space Flight" (Smithsonian Traveling Exhibition). Indianapolis, Indiana. At Indiana State Museum, (317) 232-1637.

"Black Wings: The American Black in Aviation" (Smithsonian Traveling Exhibition). Mobile, Alabama. At Battleship Memorial Park, (205) 433-2703.

Through December 28
"Early Flight: 1900–1911" (Smithsonian Traveling Exhibition). Lansing, Michigan. At R.E. Olds Museum, (517) 372-0422.

December 1
"Comet Halley and the Future." Denver, Colorado. Lecture by the Planetary Society's executive director, Louis Friedman. Metropolitan State College Student Center, room 330, (818) 793-5100.

December 3
"America's Future in Space." San Diego, California. Symposium featuring members of the National Commission on Space, the National Space Society, and General Dynamics Corporation. Topics will be drawn from the commission's "Pioneering the Space Frontier" report. Reuben H. Fleet Theater, (619) 573-9222.

December 4–10
Twentieth International Symposium on Remote Sensing of Environment. Nairobi, Kenya. Conference on the use of satellite and radar sensing, particularly in developing countries. Special programs include a banquet under the stars, five safaris, and lectures on Kenyan animal life, art, and gemstones. Environmental Research Institute of Michigan, (313) 994-1200.

December 6
Blue Angel Marathon. Pensacola, Florida. The name inspires participants to strive for the perfection achieved by the Navy's Air Demonstration Squadron. Civilians and other nonperfectionists welcome. At Pensacola Naval Air Station, (904) 452-4391.

December 12–13
Geminid meteor shower. Approximately 50 meteors per hour. Two to three hours before sunrise, but full moon interferes. *

December 14–28
Halcyon days. The weeks before and after the December 21 winter solstice. Named for the bird called Halcyon, which according to legend brought tranquility by calming the wind and sea. *

Ed North

"Birds fly—men drink" is the motto of the Man Will Never Fly Society.

December 16
Man Will Never Fly Memorial Society Annual Meeting. Nags Head, North Carolina. "We will have a party and continue our crusade to dispel the myth of fixed-wing flight," says society founder Ed North. The association's motto is "Birds fly—men drink." Meeting begins "around 4 pm at the bar." At Armada Motel. MWNFMS, (919) 441-7482.

December 17
First Flight Celebration. Kitty Hawk, North Carolina. The 48th annual celebration of the first successful flight. Ceremonies include speaker Chuck Yeager attempting to set a speed record with a 5½-hour flight from Edwards Air Force Base in California to Kill Devil Hills in a Piper Cheyenne. At Wright Brothers National Memorial, Kill Devil Hills. First Flight Society, (919) 441-3761.

December 20
"Toys in Space." Buffalo, New York. The L-5 Society sponsors a "Stellar Saturday" program on NASA's Toys in Space project. Videotapes of shuttle astronauts on a 1985 mission that included demonstrations of a Slinky, yo-yo, paddle-ball, top, spring-wound flipping mouse, juggling session, and your tax dollars at work and play. Buffalo Museum of Science, (716) 896-5200.

December 22
Ursid meteor shower. Approximately 15 meteors per hour. Two to three hours before sunrise.*

December 23–January 18
"Jupiter and Its Moons" (Smithsonian Traveling Exhibition). Amarillo, Texas. At Discovery Center, (806) 355-9547.

December 27–January 25
"Black Wings: The American Black in Aviation" (Smithsonian Traveling Exhibition). Atlanta, Georgia. At Fernbank Science Center, (404) 378-4311.

"Twenty-five Years of Manned Space Flight" (Smithsonian Traveling Exhibition). Ashland, Kentucky. At Kentucky Highlands Museum, (606) 329-8888.

January 4
Quadrantids meteor shower. Approximately 40 meteors per hour. Two to three hours before sunrise.*

January 12–16
Fourth Symposium on Space Nuclear Power. Albuquerque, New Mexico. A national forum for developers and potential users of space-based nuclear power systems. At Marriott Hotel. University of New Mexico, (505) 277-4950.

January 19–February 19
"Early Flight: 1900–1911" (Smithsonian Traveling Exhibition). Glenns Falls, New York. At Adirondack Community College, (518) 793-4491.

January 20–23
United States Space Foundation Third Annual Symposium. Colorado Springs, Colorado. At Broadmoor International Center. USSF, (303) 550-1000.

February 1
"Wings Over the Ocean." Jacksonville, Florida. Seminar by E.T. Wooldridge, National Air and Space Museum. At Jacksonville Museum of Arts and Sciences. Smithsonian National Associates Program, (202) 357-1350.

"Behind the Scenes at the National Air and Space Museum." Jacksonville, Florida. At Florida Community College, Kent Campus. Smithsonian National Associates Program, (202) 357-1350.

February 2
"Winged Wonders: The Story of the Flying Wing" and *"Behind the Scenes at the National Air and Space Museum."* Gainesville, Florida. Seminars by E.T. Wooldridge, National Air and Space Museum. At University of Florida. Smithsonian National Associates Program, (202) 357-1350.

* *Call the Smithsonian's Earth and Space Report for recorded information on astronomical events at (202) 357-2000.*

Organizations wishing to have events published in Calendar should submit them at least three months in advance to Calendar, Air & Space/Smithsonian, *Room 3400, National Air and Space Museum, Washington, DC 20560. Events will be listed as space allows.*

—*Patricia Trenner*

Preserve and Protect

The National Air and Space Museum's Paul E. Garber Facility could pass for an aviation enthusiast's heaven. In front of one of its 28 buildings, a meticulously restored Spad XIII sits in the autumn sunlight. A hundred yards away, a German Focke-Wulf 190 pokes its pinwheel nose out from between half-opened hangar doors. Elsewhere, a wanderer encounters everything from a Piper Cub and a sturdy Stearman trainer to the jet engine that would have powered the planned American supersonic transport.

The Garber Facility, a 21-acre treasure trove of air and space history in Suitland, Maryland, is the Museum's storehouse and home for its preservation and restoration department. Hidden away in the facility's corrugated metal buildings are nearly half of the Museum's approximately 300 aircraft, plus models, engines, and space artifacts, a collection of items that spans the history of human involvement with flight. But although Garber is outside the limelight that illuminates the showcase downtown, it is not ignored: each year up to 12,000 visitors take the time for a by-appointment-only tour of the facility.

Inside Building 20, a bulky P-47 Thunderbolt squats heavily on its landing gear, ready for eventual transfer to the Museum. Next to the "Jug" sits a P-38J Lightning, the twin-engine "fork-tailed devil" from World War II. The Lightning has yet to be restored, and next to the gleaming P-47, its age is readily apparent.

Some find this honest wear and tear one of the charms of the airplanes at the Garber facility. One such age-worn veteran is a Sikorsky JSR-1 flying boat that was stationed at Pearl Harbor on December 7, 1941, and had searched the seas futilely for the attacking Japanese fleet. The Curtiss JN-4 Jenny in Building 20 is well preserved for its age, but the years do show up in the cracked varnish on the propeller and the age-worn fabric over its ribs. Less preserved is the *Swoose* ("half swan, half goose"), the only surviving Boeing B-17D. The aircraft, which gained its strange name because it was pieced together from several wrecked B-17s, lies disassembled.

The other items on exhibit run the

Charles H. Phillips

Grounded at Garber, the Enola Gay *undergoes restoration.*

gamut of man's experience above the Earth, from Chinese kites (the Smithsonian's first artifacts of flight, donated by China in 1876) to a banana-yellow Northrop flying wing. The gleaming Bell UH-13J in Building 20 entered the history books as the first presidential helicopter (it was one of two that ferried President Dwight D. Eisenhower around). Another presidential relic is the *Caroline*, the Convair 240 that John F. Kennedy used to campaign for the presidency. It sits outside, forlorn and wingless, but the curtains hanging in the windows could convince a fertile imagination that it is still 1960. Throughout the buildings, various experimental vehicles testify to the myriad ways man has hovered, hopped, soared, and flown in his convertiplanes, flying platforms, vertical takeoff devices, and other strange machines.

Until the outbreak of the Korean War, the Museum's collection had been housed in an unused airplane factory outside Chicago, now the site of O'Hare International Airport. When hostilities commenced, the Air Force reopened the factory and gave the flying machines an eviction notice. At that time, Paul E. Garber was a curator of the National Air Museum (in 1952 he would become Head Curator, and he is now the Museum's Historian Emeritus), and he grew determined to find a home for the newly displaced aircraft. A persistent supporter of aviation history, Garber persuaded the Smithsonian Institution to acquire some unused land called Silver Hill in Suitland, Maryland, and arranged to move the aviation collection there. Years later, the Silver Hill facility would bear his name.

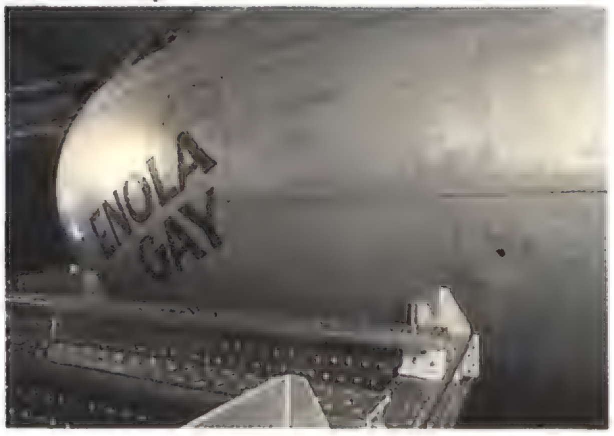
For years, the airplanes' storage conditions were, at best, horrendous. The precious relics were usually allowed to sit in the open or rot in their shipping cartons. A small staff with limited funds was unable to block the effects of time and the elements on the aircraft. Finally, in conjunction with the planning for the new Museum building, the Smithsonian found the funds to revamp and clean up the Silver Hill facility, and the aircraft were placed in new buildings to await eventual restoration.

Building 10 is headquarters for the restoration staff of 13 that labors to turn worn aircraft into pristine works for display in the Museum. Of the five works in progress, the best-known is the *Enola Gay*, the B-29 that dropped the atomic bomb "Little Boy" on Hiroshima on August 6, 1945.

Walter Roderick, chief of production operations at Garber, estimates that the *Enola Gay* project will take a total of five years to complete. "We have about a year done," he says. The bomber's front fuselage, a huge silver cigar filled with wires, dials, and oxygen canisters, is already being worked on. The B-29's aft section, another featureless cigar, rests in storage. Scattered nearby are other pieces of the airplane: flaps hang from the wall, and the airplane's tail (minus rudder) juts up from behind the *Swoose* like the fin of a great metal shark cruising through the hangar.

Merely putting the airplane together would be an enormous task, but the restoration crew has to do much more than that: each part must first be treated and chemically protected. "We preserve the internal and the external," Roderick says. "Lines, gas tanks, oil tanks are all cleaned, treated, and preserved. The main drive is to preserve the original as much as possible." Preserve they do: after the facility's metals expert, Wil Powell, treats bomb-bay clamps from the *Enola Gay*, they look brand new.

Charles H. Phillips



Five years of painstaking work will have the B-29 looking like new.

Historical accuracy, not airworthiness, is the purpose of the restoration process. "We replace only the portion that needs to be replaced," Roderick says. "If a bearing should normally be replaced because of wear, we don't worry about it as long as there's nothing wrong with its appearance. If you've been a mechanic for an airline or the Air Force, that's one of the adjustments you have to make. It takes a while to get accustomed to that thinking."

The *Enola Gay* should take approximately 13,600 man-hours of work to complete. Roderick hopes it will be finished for the opening of the Museum's proposed extension at Dulles International Airport, which awaits Congressional approval.

The Fowler-Gage biplane presents another daunting restoration task. In 1913, Robert G. Fowler flew this little craft on the first nonstop Atlantic-to-Pacific flight, a journey that lasted only one hour and 45 minutes. Fowler's secret: he flew across the Isthmus of Panama. A short hop by today's standards, in 1913 it was a risky flight over jungle that offered no possibility of an emergency landing. At the end of the trip, Fowler ran out of fuel and had to make a dead-stick landing on a coral reef.

The reef wasn't as destructive to the airplane as time has been. In its prime the biplane looked like a flying bathtub, but today the scattered ribs and torn fabric don't look like much of anything. What little fabric is left on the disassembled structure is torn and decayed, the wooden spars have rotted, and the few metal parts are rusted.

The airplane's wing sections are strapped to supports set aside in a corner. One has been stripped of its fabric and rebuilt with replacement parts. Each new piece wears a metal plate marked "Duplicate Part by NASM" and the date. Where a broken spar has been patched with a wooden splint, the wood bears the words "Repair made by NASM."

"That's done for the research of the aircraft in the future," says Roderick. "We figure that they will last anywhere from one hundred to two hundred years, and it would be very difficult for people then to know what parts have been replaced."

Another restoration project is a Vought OS2U Kingfisher, a World War II naval observation airplane. It was a Kingfisher that rescued Captain Eddie Rickenbacker after he crashed at sea in 1942. Nearby is a German Arado 234, the world's first operational jet bomber, a sleek airborne torpedo with a crew of one who performed as pilot, bombardier, navigator, and gunner.

One unique restoration project currently under way is a test model of an ATS-6 satellite ("In the Museum," April/May 1986). "It's really our first attempt at a spacecraft," Roderick says. "There's a lot to learn because of the different metals, structural design—different problems entirely."

And the work goes on in Building 10 as the Garber craftsmen slowly and painstakingly salvage history from the ravages of time. "We've restored 55 aircraft since 1959, when the restoration program started," says Roderick. "We're gaining on 300 in the collection, so we've reworked roughly one-sixth. In the next 100 years we should have it all done."

Model Subjects

It's impossible. The Museum's P-47 Thunderbolt is too big to put on your mantlepiece. But you can have the next best thing: a Revell scale model of the aircraft that is so up-to-date it got its official paint job before the real one did.

The Revell Plastics Company, of Venice, California, now produces a series of aircraft models based on airplanes from the Museum's collection. Included are the P-47, P-40E Warhawk, F4F-4 Wildcat, F4U-1D Corsair, P-51D Mustang, and the Hawker Hurricane Mk.IIC. (The real Thunderbolt, Corsair, and Hurricane are in storage at the

Charles H. Phillips

Pilots for Revell's P-40E and F4U-1D were assembled, not trained.

Garber facility.)

"The idea's been kicking around for years," says Sue Bates of the Smithsonian Institution's Products and Licensing Division. Revell contacted the Smithsonian with a plan to revamp some of their existing model kits, design new decals and paint schemes, and package the models as replicas of Museum aircraft. Museum curators chipped in with background information on each aircraft for the instruction sheets. Revell photographers then took the airplanes' mug shots for the model boxes. In the case of the P-47, which is at the Garber facility awaiting a new paint job before replacing the Grumman Hellcat downtown in 1988, the model has received its new colors before the real thing, an authentic case of life imitating artifice.

Space Tracking

The new resident in the Museum's Space Hall, hanging with its twin dish antennas outstretched over the Apollo-Soyuz spacecraft, is a life-size model of part of the planned Tracking Data and Relay Satellite System (TDRSS). It's the latest word in communication between Earth and vehicles in orbit.

Since 1971, spacecraft and satellites in orbit have kept in touch with Earth via the worldwide system of ground stations in the Spaceflight Tracking and Data Network (STDN). Each of these stations communicates with spacecraft passing over it, and then performs a communications hand-off to the next station along the orbiter's route. Occasionally a spacecraft will be out of reach of all the stations, blacking out communications with it.

The TDRSS will eliminate the drawbacks of the ground station network. By putting two relay satellites into geostationary orbits, where they match Earth's rotational velocity and thus remain over the same spot on the planet, an orbiting vehicle will always be within range of at least one

TDRS. A third will orbit as a spare. "It's much simpler than the system on the ground," says Linda Ezell of the Museum's Space Science and Exploration department. "TDRSS insures coverage all the time and with a better rate of data reception." And TDRSS will be essential to such orbiting systems as the Hubble Space Telescope.

One TDRS was taken aloft aboard the space shuttle *Challenger* in April 1983, but when released from the shuttle, the satellite's engine failed to boost it into a higher orbit. Technicians on the ground were forced to resort to a delicate series of maneuvers to place it properly. A second TDRS was destroyed in the *Challenger* explosion last January.

The full-size TDRS model in Space Hall is slightly over 57 feet long and 42 feet wide. Design Models, Inc., built it for display at Japan's Tsukuba Expo '85, and TRW, Inc., donated it to the Museum.

Ezell reports that the Museum is working on a more detailed exhibit on orbital tracking for 1988. "That would give the more complete story," she says. "Right now you're getting the end without the beginning."

Eyes in the Skies

Visitors suffering from a fear of heights might think twice about entering the Museum's art gallery, where all the artwork on display springs from a higher consciousness. From balloon's- and airplane's-eye views, to glimpses of our world seen from spaceships of the mind, the art in the "Earth Views" collection presents an aerial view of the third planet from the sun.

The works displayed, employing such media as acrylics, oils, watercolors, and metals, were selected from over 600 entries in the second art contest sponsored by the Museum. Designed to complement the new "Looking at Earth" gallery, which demonstrates our increased ability to study our planet from above, the "Earth Views" exhibit is literally out of—or at least off—this world.

Woodward Payne's "Morning Mist" placed first in the Museum's art contest.

Woodward Payne/NASM

The works displayed prove the artists' abilities to leap tall buildings in single bounds of the imagination. Woodward Payne's first place winner, "Morning Mist," is an oil-on-canvas view of farming country near Modesto, California. Greg Mort won second with "Third from the Sun," a fanciful watercolor that portrays Earth as a newly unwrapped present open for our inspection. The third place winner is Mary Edna Fraser, for "Kiawah Island, South Carolina," a batik-on-silk view of her state's coast. Other works portray natural wonders ("Soaring Above the Kaibab, Grand Canyon" by Raymond Lynn Martens), manmade devices ("*Challenger* STS-7" by George McCoy), and even aviation history ("Toward the Summit" by Walter Wright, an acrylic painting of the first overflight of Mount Everest).

The "Earth Views" exhibit will run until spring, providing Museum visitors with an uplifting view of our home planet.

Museum Calendar

Except where noted, no tickets or reservations are required. Call Smithsonian Information at (202) 357-2700 for details.

December 3 Fall Film Series, 7:30 pm. Langley Theater. *Top Gun* preceded by a Navy Flight Training short. Admission $1.

December 4 General Electric Aviation Lecture, 7:30-9 pm. Langley Theater. Steve Ritchie, United States Air Force ace in Vietnam.

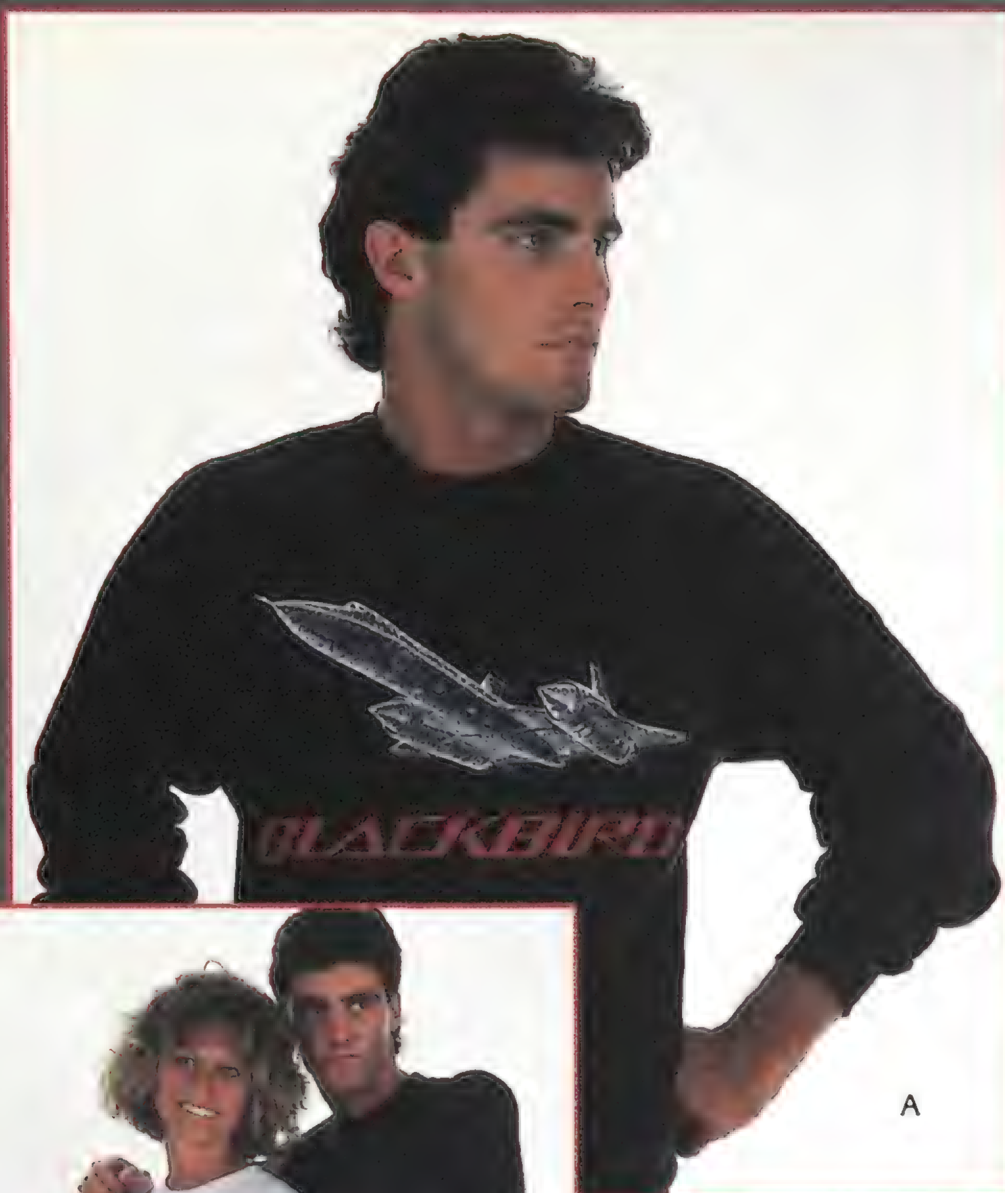
December 6 Monthly Sky Lecture, 9:30 am. "Christmas Star," Albert Einstein Planetarium. David DeVorkin, chairman of the Museum's Space Science and Exploration department.

January 4 Monthly Sky Lecture, 9:30 am. "Save the Phenomena! Ptolemy's View of the Universe." James Hyder, NASM Theater. Albert Einstein Planetarium.

January 15 General Electric Aviation Lecture, 7:30-9 pm. Langley Theater. Commander Rick Ludwig, commander of the Top Gun squadron.

Come visit your Museum on a "Washington Anytime" weekend—two nights (double occupancy) for $99. Includes accommodations, some meals, Museum tour, Smithsonian Castle tour, IMAX film. For details, call or write to the Associates Travel Program, Capital Gallery 455, Smithsonian Institution, Washington, D.C. 20560. (202) 287-3362.

—Tom Huntington



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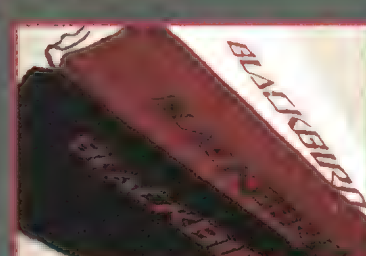

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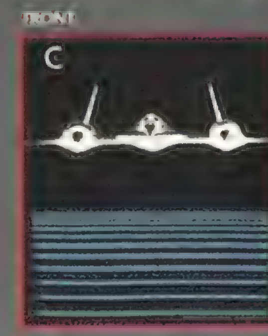

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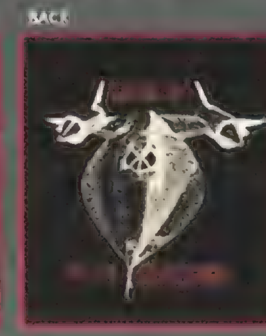

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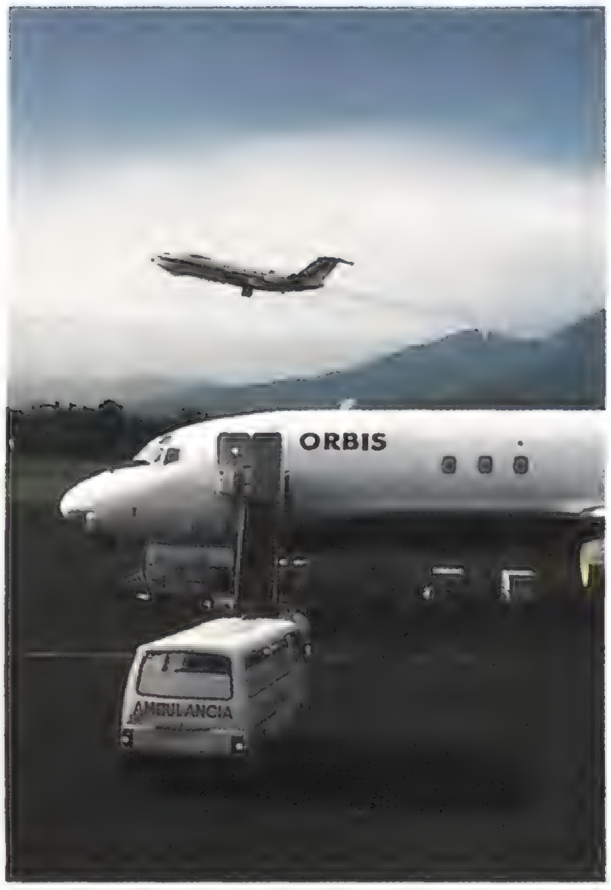
Orbis Helps the World to See

By Elaine de Man

Photographs by Jordan Coonrad



Throughout the developing world, this 20-year-old DC-8 has become literally a sight for sore eyes (above).

For many Costa Ricans with serious eye afflictions, Orbis is all that stands between them and blindness (right).

Forty-two million people in the world are blind and half a billion more, primarily in Third World nations, have some potentially blinding disease. But most ophthalmologists in the developing world are cut off from the latest medical advances. For lack of something as basic as information, blindness is a harsh fact of global life.

This is the world that David Paton, an ophthalmologist from Houston, Texas, saw 14 years ago when he conceived Project Orbis—an airplane that would circle the globe, carrying a medical team to teach sight-saving techniques at every stop. The dream became reality in March 1982. An elderly DC-8, with a fully equipped teaching hospital and a crew of doctors, nurses, and technicians on board, left the United States to begin its lofty mission.

On this day, the airplane—with a small red cross on the fuselage and a giant eye painted on the tail—is climbing out past towering volcanoes, having finished its three-week stay in Guatemala. The growl of jet engines is temporarily broken by an announcement from the cockpit: "Good morning, ladies and gentlemen. Welcome to your Orbis flight. We'll be departing to the north, then making a right turn and climbing to a cruising level of 33,000 feet. We'll eventually turn southeast along the coast to our destination in Costa Rica. So have a good time and come see us. Remember, it's your airplane."

The crew is an eclectic mix. Captain Dave Ormesher is a pilot for United Air Lines and first officer Mike Lyon flies for Pan American—they are among six pilots who volunteer during time off from their jobs. The flight engineer, Pat Healy, is also director of flight operations for Project Orbis. On days when the airplane isn't airborne, which is 95 percent of the time, he oversees maintenance and makes arrangements for the next stop. The flight attendants, Julie DiBiase and Jan Frandsen, are nurses who are more often found in sterile blue gowns, handing out sutures and medication instead of coffee and pastry. The other members of the medical team are relaxing in the airplane's classroom, strapped into their seats and leafing through magazines.

A teaching hospital crammed into an elderly airplane brings the latest sight-saving knowledge to millions of people facing a life of blindness.

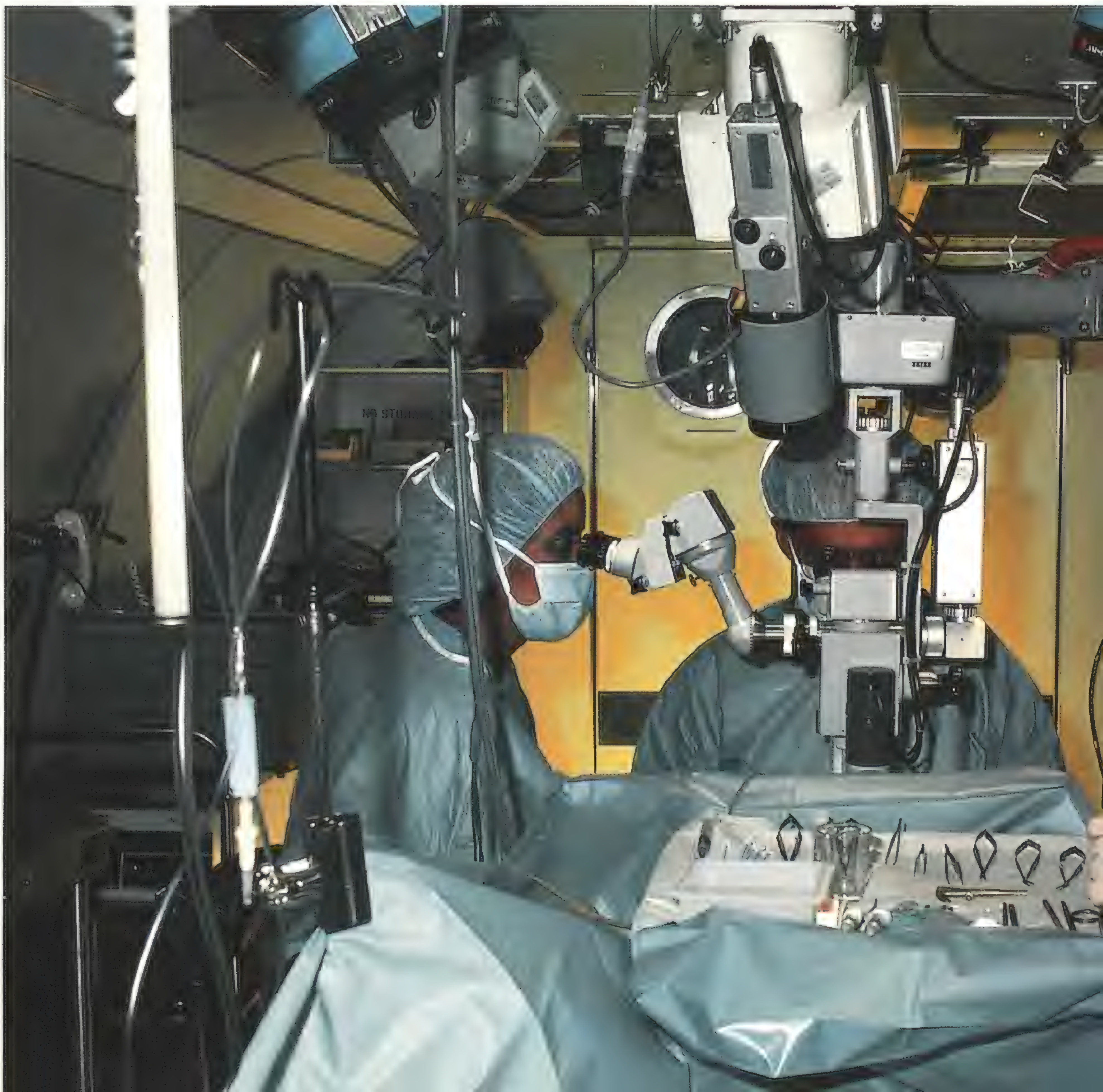
After landing in Costa Rica, all hands pitch in to turn the airplane back into a hospital. The pilots help unload luggage stowed in the recovery room—"God forbid we should lose any," one of them mutters. Healy lowers to the ground the electrical generators that had been hoisted into the belly for flight. The technicians set up the surgical equipment and convert the galley into a pre-op area. The doctors and nurses unshackle the stools in the operating room and unpack the medical supplies. Within hours the transformation is complete. Only the arched ceiling, porthole windows, and seat belts on the chairs in the classroom hint that this sophisticated hospital has wings attached.

The project takes its name from the word *orbis,* which means "of the eye" in Greek and "around the world" in Latin.

Indeed, team members have been around the world to give suffering people the most precious gift they can. But the job is not particularly glamorous. They've been flooded out in Jamaica and had to operate by flashlight in Beijing when onboard power failed. They've worked to the sound of gunfire in Iraq and operated under tight security in Egypt. Some of them have gotten deathly ill and have been robbed at gun point. The job requires a sense of humor as much as anything else. ("Well, the dog's still barking. That's a good sign," observes one of the team members during an outing to a dubious-looking Italian restaurant near the airplane's current base of operations.)

Project members have also proved adept at making do. "We originally wanted a Boeing 707," says Al Ueltschi, co-chairman of Orbis' board of directors and president of Flight Safety International, a firm that trains pilots. "But we couldn't get anyone to give us one." United Airlines eventually donated the Douglas DC-8, a 20-year-old airplane that was too small, too noisy, and used too much fuel to be profitable in a commercial world. The airplane arrived as an empty shell, but was gradually transformed into a teaching hospital the equal of any in the world.

Keeping Orbis on its rounds now costs $5 million a year. Nearly $2 million comes from the U.S. Agency for International Development, and major corporations provide money and "gifts in kind" worth about $1 million. For ex-



Seeing that portable generators keep power flowing is but one chore for Pat Healy, Orbis' jack-of-all-trades (left).

Vision problems alone can't guarantee treatment; Orbis seeks cases that will also aid its teaching mission (above).

After clearing the screening process, patients next meet surgeon Steve LauKaitis in pre-op (right).

A sea of calm aboard Orbis, the operating room has helped patients and doctors in over 40 countries (left).

ample, United helps with pilot training and airplane maintenance, Sheraton provides hotel accommodations for the crew wherever possible, and Mobil Oil donates a yearly allotment of jet fuel. "Money is still a constant problem," says Oliver Foot, executive director of the project. "It's gotten better, but we don't have any reserves."

The airplane itself is in good shape, but keeping it so means some team members stay busy. The third DC-8 off Douglas' assembly line and the oldest one still flying, it has logged some 53,400 hours. "This airplane will fly into the twenty-first century," Healy confidently predicts. "It's one of the few jet aircraft that was designed with an almost unlimited life expectancy for the airframe. Our biggest problem will be getting spare parts, especially for the engines." United still provides some parts, but Healy gets most of them from the dwindling number of DC-8s being scrapped the world over. "We're starting a program to get as many parts as we can," he says, "so that in the years ahead, when DC-8s have evaporated from the face of the Earth, we'll have a big enough supply to keep us going."

Since Orbis took off on its first mission to Panama City, the crew has visited more than 40 countries. Four thousand people have been treated free of charge, and thousands of eye-care specialists have gained new knowledge that they can put to everyday use. National leaders have also been inspired to encourage sight-saving transplants of corneas—transplanting organs is illegal or discouraged by religious and social taboos in many underdeveloped nations—and to devote more effort and money to local health care.

This is the second time Orbis has visited Costa Rica, a mountainous country about the size of West Virginia that is nestled between Nicaragua and Panama. Here, about 30 ophthalmologists serve a population of 2.6 million, one for every 86,000 people. Local doctors have been selecting potential patients for the last year, and the Orbis team screens them in a small building on a dusty side street in the center of San Jose, adjacent to Hospital Calderone Guardia. It's packed. "You have to understand," warns Victor Ramirez, one of the host doctors, "everyone in Costa Rica wants to be seen by Orbis. We have 800 patients waiting for you."

One by one, the patients file through. "They aren't even aware that Orbis is a teaching hospital," says Jeff Arnoult, a surgeon from Houston, Texas. "They just think it's a hospital from the United States and that it's the best medicine in the world. They come because they think their problem, no matter how extreme, is going to be miraculously cured somehow." Arnoult, a boyish-looking 34-year-old who would look at home in a Walt Disney movie, is one of five surgeons who volunteered to supplement the Orbis staff for this first week in Costa Rica. Right now, he must find patients who not only are treatable but will also serve as good teaching examples for the host doctors.

By mid-afternoon the Orbis doctors have seen 100 patients and more illnesses than they might see in a year at home. They've screened a lot of people who simply can't be helped, but also many who can. One of them, a blind Nicaraguan refugee, tells her doctor, "God has listened to me. I'm going to be operated on by Orbis."

For the rest of the three-week mission, Orbis will be the focus of local attention. There'll be press conferences, and pictures on the front pages of newspapers. People will line up along the chain link fence around the airport to look at the airplane, and vendors will set up stands to sell cold drinks. Ambulances will pull up beneath the wing and patients will be helped up the stairs to the airplane.

By sharing his medical expertise with Costa Rican doctors, volunteer Jeff Arnoult of Houston (right) spreads Orbis' reach far beyond the airplane's wingspan.

Rather than in-flight movies, local doctors watch operating room action on the classroom's monitors (left).

The doctors learn to cure a cataract patient by replacing a diseased lens with a plastic one (below).

Inside, it's standing room only in the pre-op area, and anyone who wants in or out has to push through all the people milling around. Orbis surgeons and host doctors confer over a set of photographic slides, with English and Spanish flying simultaneously. An air conditioning unit has conked out and Pat Healy is on the case, passing back and forth between the cockpit and the generator outside. Doctors wander in and out of the adjoining classroom. Beverly Clark, a volunteer surgeon, is showing the local doctors how to use a sophisticated laser device that can perform surgery without cutting the eye open. One of the overhead video monitors blinks temporarily to a Road Runner cartoon.

Winnie Osborne, a nurse from Vancouver, British Columbia, who's been with Orbis for 18 months, is preparing a patient for surgery. The man has been sitting quietly in the midst of the apparent chaos, trying hard not to look at the monitor showing an eyeball, a foot wide, being incised with a scalpel.

In the operating room, the heart of the airplane, calm prevails. The patient, who is having a blinding cataract removed, was given a local anesthetic to deaden his eye, but he remains awake. "Sometimes we give them a sedative," says Jan Frandsen, a nurse anesthetist from Denmark. "And sometimes we just hold their hand. That often proves the most effective."

Sitting at the head of the operating table is Olga Montoya, a Costa Rican ophthalmologist. She peers through a microscope into the patient's eye, and a camera inside the microscope projects every move she makes onto monitors in the classroom, where 18 of her peers watch. She is, admittedly, nervous. Garth Taylor, a volunteer surgeon from Ontario, sits by her side. Dr. Montoya makes a tiny incision, removes the cataract flawlessly, and reaches over to squeeze Dr. Taylor's hand. Now she will learn how to implant a plastic "intraocular" lens as a replacement.

In Costa Rica, as in most of the world, cataracts are the leading cause of blindness. What causes them remains unknown, prevention as yet impossible, and surgery the only treatment. The intraocular lens transplant is a relatively new and simple operation and the one performed most often aboard Orbis.

A question from the classroom is broadcast through the speaker in the operating room. "Doctor, do you usually polish the posterior capsule?"

"I usually do, yes," Taylor answers.

Dr. Montoya stitches up the incision as Taylor says, "It's in the bag." She breathes a sigh of accomplishment and pats her patient on the shoulder. "Muy bien," she whispers. "Esta terminado."

While such cooperation is the order of the day aboard Orbis, it would be impossible for a doctor to come to a U.S. hospital to learn surgery by doing. Dr. Montoya, for example, could look over someone's shoulder, but she would be prohibited by law from performing or assisting in operations.

"This is what Orbis is all about," says Taylor, whose speech reveals traces of a native Jamaican accent. "We could come in as visiting surgeons and just do all the operations ourselves. But when you can take medical people who have never done this surgery before and teach them how to help their fellow citizens, then it's . . . orgasmic." Taylor is on his eighteenth mission. One week out of every month, he leaves his practice and meets the airplane wherever it is. He calls it "rejuvenation."

Out in the bustling examination room, one of Taylor's transplant patients from yesterday awaits his postoperative exam. Taylor removes the bandages and covers up the man's other eye.

"How many fingers do you see?" he asks, holding up his hand.

"Five," the man replies, as a giant grin spreads across his face.

If Garth Taylor were a football player who'd just scored a touchdown, he'd be dancing around the end zone right now, waving the ball victoriously over his head. Instead, he turns away from the patient and makes a tight fist and pounds it against the air in front of his chest. Yesterday this man was blind. Today he can see.

Revolutionizing eye care in the Third World can be a matter of donating a new microscope to a hospital in Jamaica, training ophthalmic assistants in the tiny African nation of Malawi to perform cataract operations, teaching doctors how to use modern optical equipment in Iraq, bringing a hundred ophthalmic assistants in Nepal together for a workshop on primary health care, or training African "witch doctors" to detect eye disease. Or it can be as simple as inviting the president of Costa Rica to visit the airplane on a typical day.

President Oscar Arias has come on board Orbis just in time to witness a corneal transplant operation being broadcast live in the classroom. If the president is stunned by the sight of an eyeball being stitched together with a needle and thread, he doesn't show it.

The cornea used in this operation was flown in from the United States because Costa Rica's fledgling eye bank is sorely lacking deposits. More than 400 people are waiting for cornea transplants. An Orbis specialist will train technicians at the eye bank on the proper handling of the eyes, but the problem of insufficient deposits persists.

When the transplant operation is over, Orbis executive director Oliver Foot offers President Arias a look at the rest of the airplane's medical facilities. Foot is a distinguished, gray-haired Englishman, the quintessential diplomat, equally at ease with heads of state and the patients who come to the airplane for help. Since Orbis founder David Paton has moved on to become a professor of clinical ophthalmology at Cornell University Medical School (though he remains the project's medical director), Foot has emerged as the glue that holds the crew together—the driving force behind Orbis and its success.

For their medical tour, Foot and Arias pull the required blue paper booties over their shoes. In the recovery room, the president meets the man who had been under the surgeon's knife just minutes before. Foot pulls out the styrofoam container marked "Human Eyes" that was shipped last night from the United States. "Look," he says, "this man is now looking at the world through American eyes." The president grins at the little joke.

"If you, President Arias, would offer to donate your eyes to the new eye bank, then others would be encouraged to do the same," Foot adds. "For every pair of eyes donated, two Costa Ricans would be able to see. It would mean so much to your country."

"Yes, yes," the president says, "I will do this." And as he sits down to sign a donor card, the recovery room is swamped with blue-bootied reporters and cameramen trying to get past the nurses who are trying to maintain some sense of order. Undaunted, the photographers hold their cameras over their heads and snap furiously away. By 7:00 p.m. pictures of President Arias have made national television. This, says Foot, is one way that Orbis will bring sight to many Costa Ricans who will never board the airplane and may never be aware of its existence.

Orbis has steadily evolved from the dream of one man into an international harbor of goodwill, communication, and cooperation. However, the project is not without critics, some of whom point to the sophistication of the airplane's medical equipment, to which most host doctors may only dream of having regular access. Why raise hopes unrealistically, they ask, or teach surgical methods that would be too expensive for local people to afford?

Orbis members see kernels of truth in such arguments and have begun to emphasize community health activities. For example, they are now instructing local clinical assistants in nutrition and hygiene and in the detection of eye disease. Hundreds of them have already been trained in such areas as Katmandu in the Himalayas and Arequipa in the Peruvian Andes. They are becoming a veritable eye-care army that will grow with every stop Orbis makes.

Still, fighting blindness is a never-ending battle. "Everyone realizes this airplane is not going to eliminate world blindness," says surgeon Jeff Arnoult. "But it can make a significant impact, and there is no question in my mind that it already has."

The airplane's recovery room isn't only for patients—after a hard day, nurses can need it, too (left).

Surgery over, a young patient—one of 4,000 treated worldwide—faces a new life free from blindness (right).


N220RB

By Fred Reed

The Electric Jet

You can think of the F-16 as a first step toward the "smart" airplane. For its pilots, flying may never be the same again.

With its astonishing ability to turn on an aerial dime, the F-16 fighter is widely regarded as the U.S. Air Force's most maneuverable operational airplane. General Dynamics' small, sleek jet has been a huge success and is prized by all the air forces in which it serves. The United States owns most of the approximately 1,600 F-16s that have been produced since the airplane entered service in 1979, but 14 other nations either have it in operation already or are obtaining some version of it. Many others would dearly love to get their hands on it but have been turned down. Politics.

The F-16 came into being partly because of the performance of Air Force fighters in combat over Vietnam, where their success was at best only about one third as good as it had been in Korea. Air Force analysts began to wonder why. The cause was rooted in the years between the two conflicts, when U.S. military planners had decided that the traditional dogfight had become obsolete. Future fighter combat, said these seers, would be conducted at long range, with missiles. As it happened, they were wrong.

The McDonnell F-4 Phantom II was the front-line "fighter" in Vietnam, but it was originally designed as a combination interceptor and attack bomber for the Navy. The Phantom's

Photographs by George Hall

performance also impressed the Air Force, which bought a large number. Interceptors are supposed to stop bombers; fighters are supposed to counter other fighters and dominate the battlefield. The two are very different.

The supersonic Phantom was built to carry a crew of two and a powerful, long-range radar with missiles to match—but no gun. It turned out to be ill-equipped for the style of combat engaged in by North Vietnam's MiGs, which were lighter, single-seat, gun-equipped fighters that too often managed to close with the Phantoms and force a dogfight. The Phantom was large and its engines smoked, and those drawbacks made it too easy to spot at a distance. Both faults are more serious than they might seem: something like 80 percent of airplanes lost in combat never see their attacker. Phantoms eventually got their own cannon, but the airplane's size and weight remained liabilities.

Out of this experience, a group of Air Force proponents of a small, fast, extremely maneuverable fighter drew considerable encouragement. The "lightweight fighter" program gained sufficient momentum to award contracts to General Dynamics and Northrop, and both companies began building competing prototypes. The winner could look forward to a huge contract

to produce thousands of airplanes, with enormous sales potential overseas. General Dynamics' single-engine YF-16 (the Y prefix identifies a prototype airplane) won and became the F-16 Fighting Falcon. Northrop's entry, the twin-engine YF-17, rebounded later as the Navy/Marine F/A-18 Hornet, on which Northrop partnered with McDonnell Douglas.

But the lightweight fighter had to clear still more hurdles: within Pentagon circles where wrangles over weapon systems are conducted, proponents of the agile fighter charged that between the YF-16 and the F-16, the Air Force "heavied up" the fighter too much with extra electronics, particularly radar, so that the F-16 could do more work. The "fighter mafia" (the name given to the group of lightweight fighter zealots) regarded the changes with scorn. But the radar stayed and has even been enhanced over the years.

The "multiple role" F-16 that finally emerged represents a fusion of competing doctrines. But the argument about the best way to build a fighter has become moot because the airplane is clearly more than just a better fighter; in fact, it has

nullified the debate by redefining the way a fighter flies. The F-16 is a remarkable conceptual leap for the Air Force. It embodies a wholly new approach to aircraft control and maneuverability made possible only by computers. Computers actually determine how the airplane flies; indeed, without their electronic supervision the F-16 cannot be flown.

The aerodynamics of maneuverability is at once a black art, depending on the designer's taste and intuition, and a fearfully mathematical enterprise that can gobble weeks of time on the fastest computers available. Yet the fundamental concepts, including those that make the F-16 unusual, can be comprehended without a lot of math.

A good fighter should turn like a sports car and be faster than a bullet. You'd therefore think it should have maximum lift and thrust with a minimum of drag. But the design of any fighter is a product of trade-offs because of the way the airplane's desirable qualities tend to work against each other. For example, lift by its very nature produces drag: if you give an airplane large wings that provide lots of lift at low speeds and also provide a lot of surface to grab the air for tight turns, you get too much drag at high speed. If you use movable wings that can vary their sweep to obtain the best lift characteristics for a given speed—as the B-1, F-111, and F-14 do—the airplane's weight goes up sharply. Even more frustrating, airplanes behave quite differently at supersonic speeds, so that an airplane

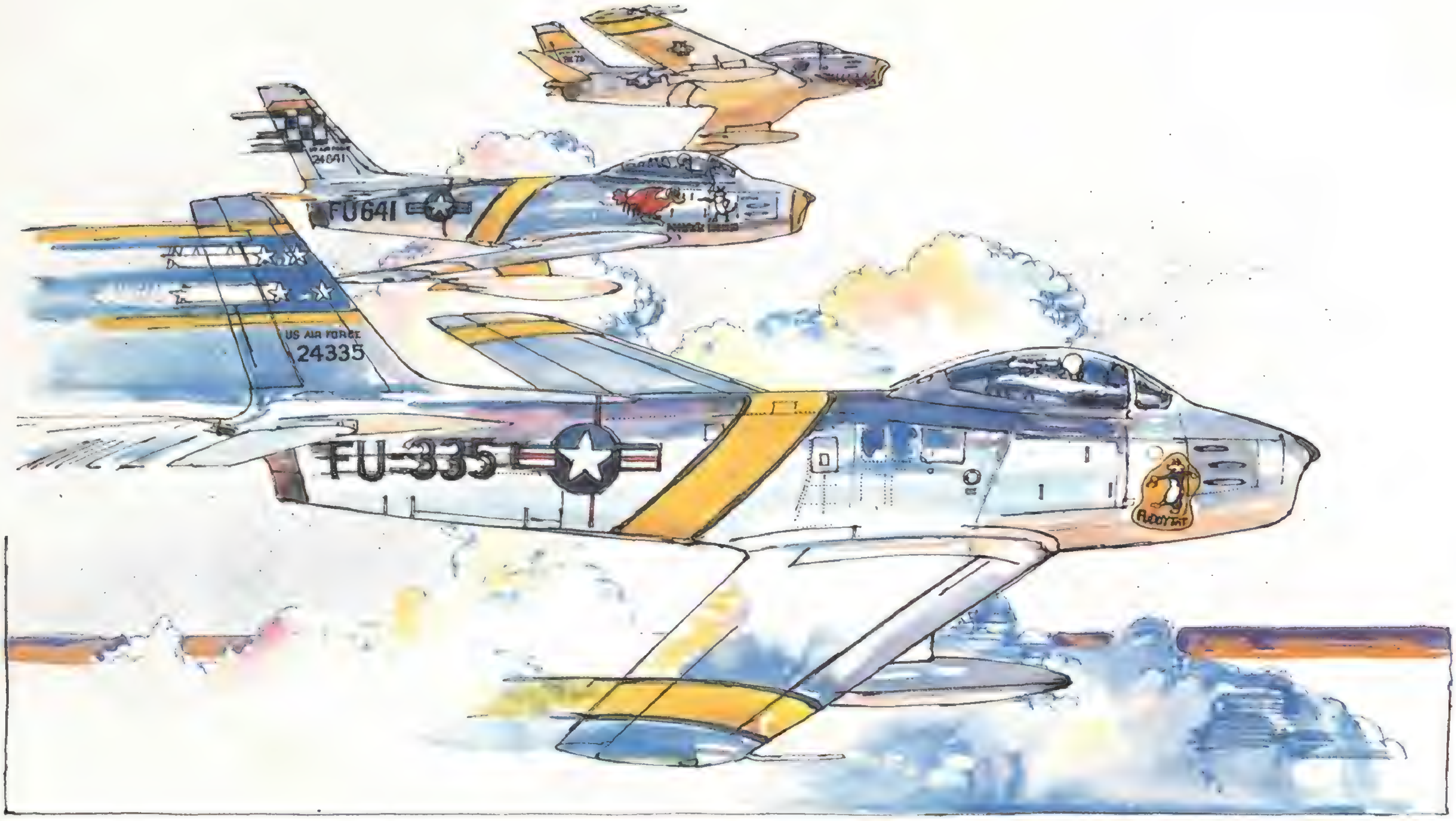
designed for good subsonic performance may have excessive drag at supersonic speeds. So engineers compromise.

One of the most important factors affecting maneuverability is how fast an airplane's control surfaces can move it around its axes of motion. In the Korean war, pilots made the unwholesome discovery that Soviet MiGs were superior to the North American F-86 Sabre at some aspects of combat maneuvering. However, the Sabre could "transition"—go from a left turn to a right turn—more rapidly, in part because it had hydraulically assisted control surfaces. Sabre pilots learned that if they could force their adversaries to change direction rapidly, the Sabre could outmaneuver them.

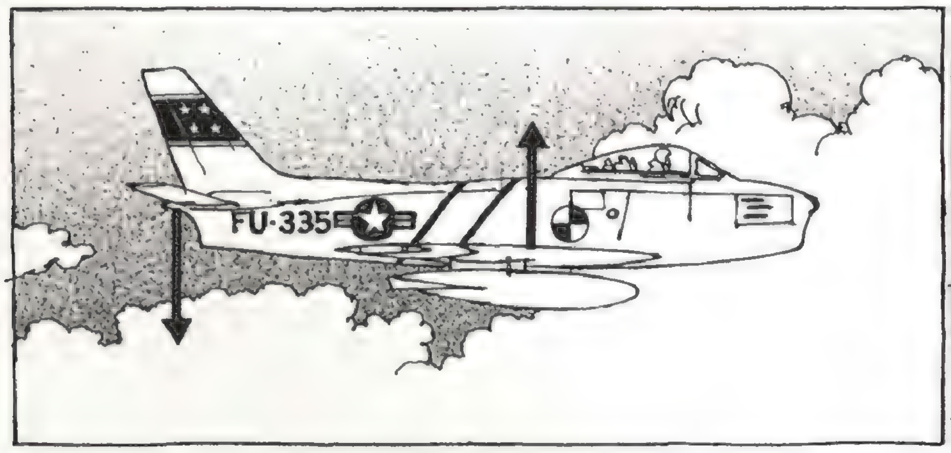
Most aircraft have mechanical linkages—cables are typical—to move the control surfaces as the pilot moves the controls in the cockpit. The *distance* the pilot moves the control stick or pedals directly determines how far a control surface will deflect. Pilots may not be strong enough to move the surfaces of very fast or very large aircraft against the force of the passing airflow, so hydraulic systems are added to multiply their strength and help pull on the cables.

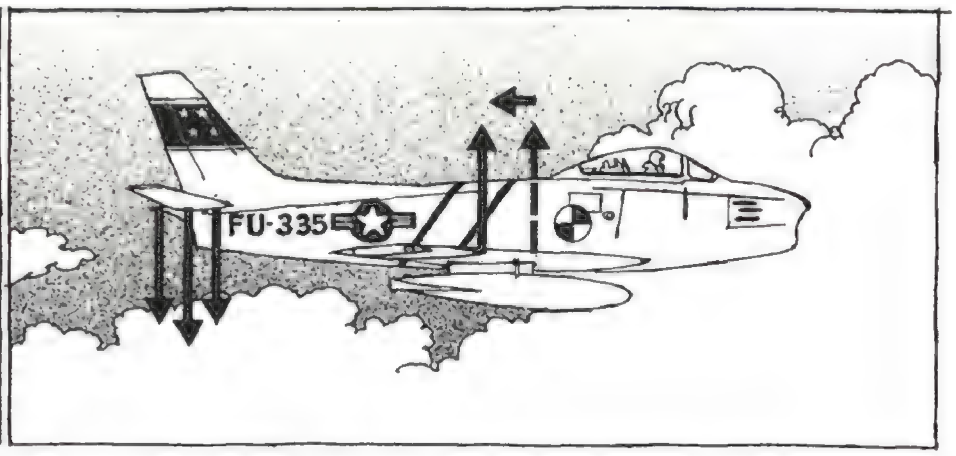
The F-16 departs from traditional mechanical controls. It is controlled with a "fly-by-wire" system in which electronics sense the *force* of the pilot's pushing and pulling on the controls and send electrical signals to hydraulic actuators that move the control surfaces. Replacing mechanical linkages with electrical circuits reduces weight. More importantly, it allows a computer to be inserted in the electrical circuit—the perfect place for supervising the pilot and preventing his doing things that might lead to loss of control. For example, if a pilot were to pull up too sharply at a low speed, the aircraft would "stall"—lose lift and go out of control. To avoid stalls in an older-generation fighter, the pilot had to watch an instrument that displays the "angle of attack" between the wing and the passing air—and pilots don't like to watch instruments when they're in a dogfight. By contrast, an F-16 pilot can maneuver with abandon, knowing the control computers won't let him pull the nose up enough to cause a stall. The computers also automatically adjust the flaps on the leading edge of the wings according to speed and angle of attack so that the airflow remains smooth and the wing won't stall.

But a more important peculiarity of the F-16 is that it is inherently unstable in flight. Making an airplane uncontrollable by humans seems to be a mistake, but there are good reasons for it, and all future fighters will probably be intentionally designed to be unstable.



Illustrations by Ken Dallison



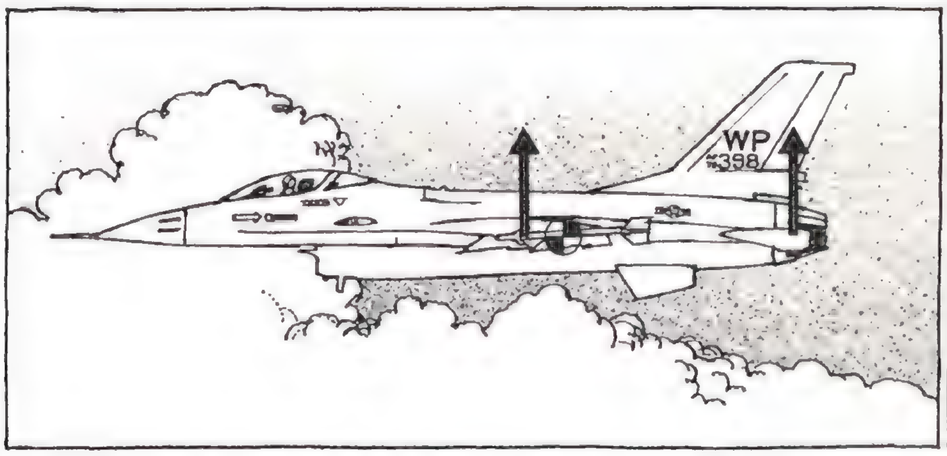


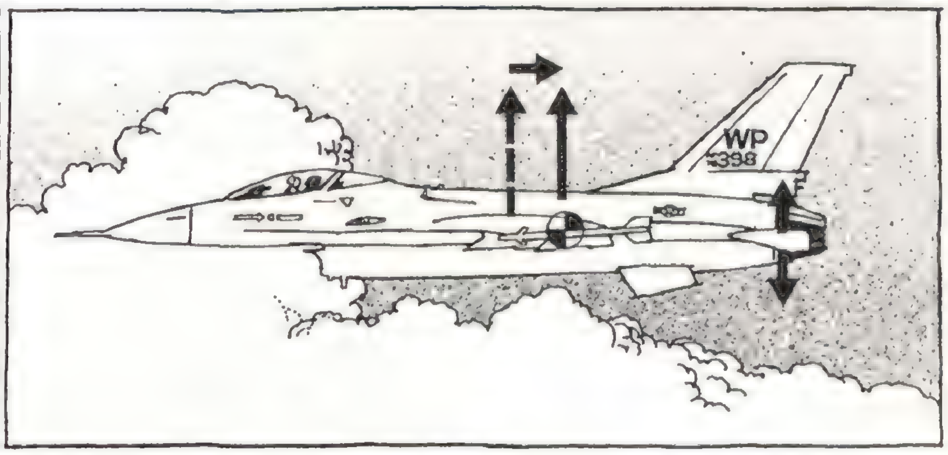
Subsonic in the 1940s—a piece of cake

The North American F-86 Sabre typifies post-World War II design in a single-seat fighter. Its wing and tail arrangement follows traditional practice in order to achieve aerodynamic stability: the effective center of lift (symbolized by an arrow pointing upward from the wing) is located aft of the center of gravity (symbolized by the circled cross). To balance the airplane in flight, the Sabre's horizontal tail surfaces produce a force acting downward; the combined forces keep the fighter stable.

Supersonic in the Sabre—a handful

When the Sabre exceeds the speed of sound—Mach 1—the conventional design becomes a handicap despite its inherent stability. At supersonic speeds, the center of lift shifts rearward. Now the airplane has a strong tendency to pitch nose down, and to compensate, the horizontal tail must work harder to produce a balancing downward force to keep the nose level. To create this increased force, the tail deflects more of the passing air, which creates drag and slows the Sabre down.





A new arrangement— the Fighting Falcon

The F-16's design benefits from years of experience with supersonic aerodynamics. Its wing is arranged so that the center of lift is forward of the center of gravity, which tends to lift the airplane's nose. To balance that, the horizontal tail creates a lifting rather than downward force. Making both wing and tail surfaces create lift is inherently efficient—but unstable. A computer restores the stability artificially, and the airplane's configuration now confers an overall plus: improved maneuverability.

Today's technology— even happier at Mach 1

When the F-16 transitions to supersonic speed and its center of lift moves rearward—just as it does on the F-86—that rearward shift acts to reduce the work the horizontal tail must perform. With the lift now acting through a point closer to the center of gravity, the airplane has less tendency to pitch upward. In turn, the tail has less work to do keeping the airplane in balance. Less work means less drag to slow the fighter down when it's flying faster than the speed of sound.

George Hall

Life at Six Gs

Five hundred feet over South Carolina at 500 knots. Below us, isolated farms and patches of forest whip past. A mile to the right, our wing man hangs in space, hardly seeming to move. The oxygen mask presses against my face like the heel of a clammy hand and, I know from experience, will shortly begin itching unreachably. The cockpit is small, the canopy large and very close around my shoulders. The effect from where I sit is one of flying *on* the airplane rather than in it.

Flying the F-16 is brutal. Accelerative G-forces, generated whenever this nimble airplane maneuvers, are crushing if you are not accustomed to them. The seats recline at a 30-degree angle to increase the pilot's tolerance to Gs, but the improvement is marginal. Aeromedicine says the best angle is perhaps 65 degrees, but it is not clear how to fly or use the ejection seat when you're lying down.

We are wearing G-suits—"speed jeans," to the fighter jocks. The worst effect of G-forces is to force blood from the head into the lower extremities, causing blackout. The suit's legs are therefore very tight and cinched with elaborate laces to make sure they stay that way. Their pressure makes it difficult for blood to drain into the legs. This suit, fitted to me this morning, is almost painfully tight at flight time. "People who don't fly much get psyched up," the sergeant had told me. "Adrenaline dilates blood vessels and your legs swell. Really." That's how tight they are.

The G-suit also has a rubber bladder that lies firmly against your abdomen, and a hose connects the bladder to an air outlet near the seat. When a sensor detects increasing G-forces, the bladder inflates, keeping blood from pooling in the abdomen. It is becoming clear that the limit to the F-16's maneuverability is the pilot.

Our biggest worry on this mock bombing mission is hitting a bird. At over 500 mph, an encounter with one duck would knock the fighter out of the air. The pilot, Air Force Major Greg Robinson, keeps a sharp lookout for anything dressed in feathers. He also monitors the HUD, or Head-Up Display, which projects data onto a glass plate on top of the glare shield so that he doesn't have to look down at his gauges. The HUD provides all sorts of great information—speed, altitude, bearing, where the bad guys are, the Dow-Jones averages.

If the F-16's radar detects an airplane ahead, a small green box appears on the HUD. The pilot just looks through the box, and when the airplane is close enough to see, that's where he'll find it. The radar is good, but it won't pick up ducks.

The ride is smooth, maneuvers effortless. Whatever the engineers did with this airplane, it worked. The F-16 can attack from an altitude of 300 or even as low as 100 feet to avoid hostile radar and ground fire. This requires a very good pilot, which Greg is. Would that I were a braver passenger—looking down at trees is one thing; looking up at them is another.

The electronics are a gadgeteer's dream. The computers provide every conceivable bit of information: ranges, bearings, time-to-target, when to turn, and lots more. The bombing system consistently wins in competition. Pilots say they were initially suspicious of the complexity but aren't now.

The screen says we are approaching the target: time to hold on tight. We are going to pop up briefly to find the target and then dive to bomb it—a standard maneuver. Maneuvers in the F-16 are sharp and crisp, which means violent and uncomfortable. The miles-to-target counter goes to zero. "Popping up," says Greg as casually as if we were doing something reasonable. Pilots are . . . "self-confident" is an inadequate description. They divide the world into fighter pilots and people to be treated courteously despite their inadequacies.

The nose shoots up sharply, a great weight falls on me from nowhere, and the Earth recedes. "There—rolling in!" The airplane leaps on its side, turning hard and down, and suddenly the Earth sails over the cockpit: because G-forces push you into the cockpit, "down" is sensed in relation to the airplane. More weight, several Gs. I tighten my stomach muscles and grunt hard—standard behavior to hold the blood high, but not calculated to add to the dignity of the enterprise. This stuff is physical. The ground comes charging up at us.

Unnh! Five or six Gs as we bank hard to avoid imaginary ground fire and scream down toward the forest to escape at low level. A concrete truck parks on my chest. My arms won't move. I force my head back. It weighs 75 pounds at five Gs, and if I lean forward, it will land in my lap and I won't be able to lift it.

We finally straighten out, flying smoothly, once again alert for birds. South Carolina is lovely in the bright sunlight.

—Fred Reed

Stability depends directly on how the airplane is balanced in flight and has a lot to do with maneuverability. An airplane's center of gravity—engineers shorten it to CG—is a theoretical point at which all its mass is concentrated and which can be thought of as its balance point. All maneuvering motion takes place around the CG, as if it were a kind of central pivot. For example, when the pilot pulls back on the stick to raise the nose, everything in front of the CG rotates upward and everything behind it rotates downward.

Every airplane also has a center of lift, which is not as easy to visualize as the CG. The center of lift is the point at which all the lift acts as if it were concentrated. On most airplanes, all the lift comes from the wings. But on the F-16, both the wing and fuselage contribute; the engineers use the term "wing-body lift." The single point through which the sum of all the lift appears to act is the center of lift. Whereas the CG is fixed by the airplane's mass, maneuvers and variations in speed cause the center of lift to move around.

The relative positions of the center of gravity and the center of lift affect how the airplane is balanced in flight and are absolutely crucial to stability. On a conventional airplane with its horizontal stabilizer in back, the center of lift, acting upward, is behind the CG's pivot, and the downward force of the tail balances the airplane. If a gust of wind should disturb the airplane and cause it to pitch up and climb, it will slow down. Now the balancing force of the tail decreases because the air flowing over it has slowed. The force of the wing's lift, acting behind the center of gravity, pitches the airplane's nose down and restores it to level flight. This airplane is easily controlled, but it doesn't want to maneuver sharply. It likes sedate, steady flight, and engineers describe it as stable.

Now consider the situation in which the center of lift is in front of the CG. If the nose rises even slightly, the wing's lift, which is ahead of the CG's "pivot," can't restore it to level flight; instead, the lift pushes the nose even higher, rotating it upward around the CG, so that the airplane, left to its own devices, would flip over backward, out of control. In theory, the pilot could use the controls to bring the nose back down, but in practice his reflexes aren't fast enough. The airplane is unflyable. It wants to maneuver sharply but overdoes it—catastrophically. Older books on airplane design say this "static instability" is unequivocally bad.

The advent of small, powerful, reliable computers changed things greatly. "Aha!" engineers said in effect a few years back, "computers think very quickly indeed. Suppose we put computers into the control system together with sensors so they could tell what the airplane was doing. The computers could move the control surfaces almost instantaneously to correct for the airplane's tendency to diverge from normal at the slightest touch. Then the pilot could get the very quick turns that result from instability, but the computers would keep the airplane from going out of control—the best of both worlds." Being engineers, they rushed off for their pliers and wire and things, and discovered that the idea worked. And the F-16 was the first fighter to take advantage of it.

The F-16's three computers (a fourth acts as a spare) manage the controls, judging what the pilot wants to do from the forces on the stick and rudder pedals. Sensors measure the pressure of the passing air against the airplane, which allows the computers to calculate its speed. Other sensors measure the angle of the airflow, from which the computers derive the airplane's attitude with respect to the relative wind passing it. In short, the pilot's commands and the airplane's performance information are resolved in the computers.

This method is more radical than it would first appear. With the computer helping out, the pilot has much less to think about. For example, the F-16's cannon is mounted off to one side, so its recoil tends to skew the airplane slightly off course. In the heat of combat, considerable skill and attention would be

George Hall

needed to offset that sideward kick. When the F-16's computer senses that the trigger has been depressed, it automatically deflects the rudder to offset the recoil. Should the airplane be carrying external bombs or fuel tanks that change its response to the controls, the computer can adapt to keep the airplane within safe handling limits. In effect, the computer determines the airplane's handling qualities, which means that it can make the F-16 fly more like a fighter when it is stripped for action or more like an attack bomber when it is laden with ordnance. The role the airplane fills is no longer defined by its design but by what the computer says it is. And that's what has blurred the definition of it as a "fighter."

Because the F-16's center of lift is ahead of its CG throughout the subsonic speed range where it spends most of its time, the airplane's horizontal tail balances the airplane by producing its own upward lifting force, similar in effect to a small wing. On traditional fighters with conventional stability, the CG is ahead of the center of lift, and the tail pushes downward—in an airplane trying to stay *up*, a most counterproductive direction—to maintain the airplane's balance. The picture gets even worse when the traditional fighter goes supersonic. The center of lift invariably moves rearward, and now the fighter gets really nose-heavy. It takes a considerable amount of extra work by the horizontal tail to maintain balance. In the process, the tail creates lots of drag. But when the F-16 goes supersonic, the center of lift shifts rearward—closer to the CG—and the tail's job is made easier as drag is reduced.

Although the computers confer advantages, the obvious worry is that they might fail, leaving the airplane uncontrollable. But the engineers thought about that, too, and designed a system in which all the computers "vote." If one computer goes awry and comes up with a different answer, the other two

override it and call the back-up computer into action. Despite all the precautionary built-in duplication, some people still worried that unreliability of the electronics might lead to accidents. In fact, reliability has not been a problem for the F-16.

Just tinkering with stability isn't enough to achieve maximum maneuverability, however. Two important though less obvious factors are the airframe's weight and strength. In turns, an airplane is subjected to "G force" that has the apparent effect of increasing its weight. In a two-G turn, an airplane's apparent weight doubles; in a four-G turn, it quadruples. The wings have to support the increased weight; if they can't, they may simply break off.

The more sharply an airplane turns, the greater the loads imposed and, therefore, the greater the penalty imposed by extra weight. In a nine-G airplane like the F-16, every extra pound of weight translates into nine pounds that the wings have to support in hard turns. The ratio of total weight to the surface area of the wings is called "wing loading," and it should be as low as possible. One way to reduce the ratio is to increase the wing area, but that produces increased drag; the only other way is to lighten the airplane.

Another factor important to maneuverability is the engine's thrust: a light, powerful airplane can climb and accelerate faster. The F-16's big engine confers what might be called "vertical maneuverability"—the airplane has more thrust than weight and can therefore climb straight up. If an enemy fighter gets behind you and you can climb at a higher speed and angle than it can, then it can't follow.

Further, "excess power"—meaning power above that needed to maintain speed in level flight—permits sustained turns. High-G turning requires a lot of lift to oppose the greatly increased weight, but that same lift creates drag that bleeds off speed rapidly. Consequently a moderately powered craft may be able to turn briefly at eight Gs, but it slows down so much that it has to straighten out quickly or fall out of the air. Slow-moving airplanes also make easy targets, so a pilot who finds himself at low airspeed wants to "get his energy up"—*now.* This, not a desire for high maximum speeds, is why fighters have large engines. (A fighter may be able to reach Mach 2.5 but will drink enormous amounts of fuel doing so, and most combat takes place at "transonic" speeds—a little above and below the speed of sound.)

The F-16 uses an afterburner-equipped turbofan, the Pratt & Whitney F-100-PW-200, which has 23,840 pounds of thrust—a lot of engine. Soon it may get an even more powerful engine: the General Electric F-110-GE-100, a modification of the 30,000-pound-thrust engine used on the B-1B bomber. Given that the F-16 weighs only 22,000 pounds at combat weight, it is well-powered. The little fighter will hold a nine-G turn without losing altitude until it runs out of fuel—a horrible thought to anyone who has tried prolonged high-G flight.

The F-16 has been an extremely successful fighter, performing well in combat. And its performance may never be improved upon, because its maneuverability already pushes the limits of human tolerance. Pilots cannot stand acceleration forces much in excess of nine Gs, at which point a 200-pound man weighs 1,800 pounds. Looking at it another way, he is supporting the weight of eight other men like himself. Aircraft can be strengthened, but pilots can't, and the point eventually comes at which internal organs begin to tear loose. Pilots are beginning to suffer hematomas, small purple spots on the skin caused by bursting of blood vessels. There will be no piloted 15-G airplanes.

However, the principle of unstable flight is being extended, at least for research purposes. The Grumman Corporation has successfully flown its X-29, a strange-looking craft with wings swept sharply *forward.* It is intuitively obvious to almost anyone looking at the X-29 that it would be uncontrollable without some help, and its dependence on computers will be even greater than the F-16's. The X-29 is still experimental, but Grumman reports promising results.

Computers are doing more and more of the work of flying these new breeds of aircraft, and some critics say that pilots are in danger of becoming mere advisors to the electronics. The next step in aviation may be even more revolutionary: unmanned fighters flown by remote control. Pilots don't like the idea at all, and argue, correctly for the moment, that technology can't produce an unmanned airplane as effective as a manned one. Yet such airplanes could be far smaller, lighter, and stronger, and maneuver far more sharply. That way, sooner or later, lies the future.

Mi Seitelman

Flight Fantasia

The first frequent fliers weren't business people but angels, gods, horses, men, and women—all the creations of painter Giambattista Tiepolo.

A.G.E./Woodfin Camp (3)

By Frank Getlein

Think of human flight and two inaugural dates jump immediately to mind: 1783, when the Montgolfier brothers' hot air balloon carried a couple of courtiers from the court of King Louis XVI on a 25-minute voyage 500 feet over Paris; and 1903, when the Wright *Flyer* made a series of lower, shorter, and infinitely more important hops over the barren dunes of Kitty Hawk.

But there's a third, much earlier, milestone: 1305, the year that Italian painter Giotto di Bondone began decorating the Arena Chapel in Padua with scenes from the life of Christ. According to art historians, that great series of paintings initiated Renaissance art and laid the groundwork for modern painting. Often overlooked, however, is that Giotto also began the convincing depiction of human flight. His images of flight convince even today, though we have long known that his aeronautical principles, based on bird flight, were hopelessly, wildly, wrong.

As Renaissance painting flowered in Florence, triumphed in Rome, and dazzled in Venice—something like jazz coming up the Mississippi from New Orleans—artists successively increased their mastery of human flight. At first they added wings to their figures, like angels, but then they stopped bothering about those extra limbs—saints simply swooped on their own spiritual power. On the ceiling of the Vatican's Sistine Chapel, God and the heavenly entourage all drive through the air dynamically and winglessly. Indeed, Michelangelo seems to be letting us know throughout this sequence of paintings that the power of flight is a blessing worth working for.

Oddly, or perhaps not, the Renaissance painter who knew the most about how human flight could really be done never tackled the matter on canvas. Leonardo da Vinci studied flight for 25 years, and you can only conclude that he didn't paint airborne people because he knew better.

Happily, most artists didn't know better, and flight paintings proliferated, especially in Venice. The most glorious visions of human flight came from Giambattista Tiepolo. Giambattista—the Venetian version of Giovanni Battista, or "John the Baptist"—was born in 1696, when the city of canals still called itself the Most Serene Republic. Venice's heyday as a cultural, political, and financial capital of the Mediterranean was long past, and so too were the renowned artists who had celebrated the city's opulence: Jacopo Bellini and his sons Gentile and Giovanni, Titian, Jacopo Tintoretto, and Paolo Veronese. Still, Tiepolo soared.

He got his first commission at 17, and became a full-fledged member of the Venetian guild of painters before turning 21, something unheard of. During his formative years, Tiepolo was particularly influenced by the work of his great professional ancestor, Veronese, whose paintings were ubiquitous in Venice and featured architectural illusionism, spacious scenes, and—of course—flight. Before turning 30, Tiepolo was perfecting his aerial ballets, leaving his masters and models behind him, penetrating the light of heaven and peopling it with levitating, flying, floating, swooping saints and angels, rulers and aristocrats. He also launched the gods and demigods of Greece and Rome: Tiepolo, like the great Renaissance philosophers, had no problem reconciling the Judeo-Christian tradition with that of the classical deities. The Holy Trinity coexisted with Jupiter, Zeus, and an endless proliferation of pagan

In the 1760s, Giambattista Tiepolo painted a flurry of flying figures on a ceiling in Madrid's Royal Palace. Aerial perspective hasn't been the same since.

In The World Pays Homage to Spain, *Italian artist Tiepolo pays his respects not only to the royal family, but also to the notion—which would not be realized for decades—of human flight.*

Scala/Art Resource

Scala/Art Resource

The dour face of Würzburg's royal "Residenz" belies the ethereal abandon of Tiepolo's painted interior (above).

Apollo's galloping steeds have no need for wings as they carry Beatrice of Burgundy to her fiancé (right).

divinities in the boundless skies Tiepolo created so effortlessly. There was plenty of room for any god, anytime.

The reason there was room was Tiepolo's matchless command of perspective. "Perspective" is what allows the viewer to perceive depth in a painting, to imagine that a three-dimensional scene has been captured on the painter's two-dimensional canvas or other flat surface. Early Renaissance painters typically used obvious architectural "lines of recession" to add depth—geometrically patterned floors were particularly popular, because it was relatively easy for artists to figure out how the floors' patterns should be distorted with increasing "distance" from the viewer.

Most artists concentrated on establishing this feeling of depth at ground level, because that is where the action usually was in their paintings: the sky was generally conceived as a simple blue bowl fitted over the earth at the horizon. But Tiepolo introduced perspective into his skies, making his paintings seem "open" from bottom to top. And he achieved this heavenly perspective fluidly, without resorting to obvious lines of recession, by filling his skies with gradations of light that render a sense of infinite volume. This was exactly the perception that proved to be fundamental to aviation and even more so to space flight.

In these spacious skies, Tiepolo's flying figures seem almost randomly assembled one beyond the other beyond another, seemingly forever. Moreover, the figures are usually in motion. Pictorially, this derives from Michelangelo's revolutionary depiction of God the Father as a vigorously mobile ruler and creator of the universe, not just a wise old man sitting on a cloud. But for Tiepolo that dynamic conception applied even to

men or gods who *were* sitting around on clouds.

Although Tiepolo's skies may be seen—indoors—all over Venice and in the villas of the city's suburbs, his two greatest achievements were for commissions in Spain and Germany, then known as the Holy Roman Empire. He thus set an unknowing example for Wernher von Braun and many of his countrymen: just as the greatest achievements of German rocketry have taken place in the United States and the Soviet Union, so too were the Venetian master's supreme works created in foreign lands. In Tiepolo's case, the explanation was perhaps simpler: as Willy Sutton would declare much later about why he robbed banks, "That's where the money is."

In 1750, the prince-archbishop of Würzburg asked Tiepolo to decorate—in those days that meant painting, not choosing upholstery and drapery—the public rooms of his mansion in the capital city of Franconia, a province of Bavaria. After lengthy negotiations, Tiepolo went to Würzburg accompanied by his 23-year-old son Domenico, who served as his assistant, and Felice Bossi, a master stucco artisan. The trio, with some "gofer" help from the painter's second son, 14-year-old Lorenzo, worked for three years. What they accomplished is one of the wonders of European art.

Tiepolo filled one great ceiling with the flying horses of Apollo, Greek god of the sun, music, and medicine, to list just a few items in his job description. The three horses gallop in thin air, leaping off a cloud and pulling a spectacular chariot behind them. Apollo, of course, holds the reins, and his passenger is the princess Beatrice of Burgundy (better known today as the home of famous wines), who is being rushed to her fiancé. The lucky groom-to-be is Barbarossa ("Red Beard"), a German emperor of the twelfth century, who won his focal place on the ceiling because he had appointed Würzburg's first prince-archbishop. An angel flies above Barbarossa's head, another at his feet bears his state sword, and a troupe of aerialist angels tumbles and leaps all around.

Tiepolo's other great work in the mansion is on the ceiling and adjoining walls over the grand staircase, which is truly grand. Here the theme is Olympus, the heavenly home of the

Giraudon/Art Resource

Giraudon/Art Resource

After her escapade with Apollo, Beatrice is ready to settle down with Barbarossa, an early German emperor (above).

The prince-archbishop of Würzburg might well have thought that Tiepolo had built him a stairway to heaven (left).

Greek deities, surrounded by the four continents. That's right, four: Europe, Africa, Asia, and America. (To this day in much of Europe, "America" can mean Rio de Janeiro as easily as Chicago.) Above the continents the sky is filled, as always, with flying figures. Hovering over "Europe" is, of all things, the wreathed portrait of Carl-Phillip von Greiffenklau, the very man who was paying the painter and, clearly, calling the tune. The prince-archbishop seems to be staring at the nearby nude figure of a handsome young woman blowing a trumpet, the symbol of fame. Sycophancy? You bet. Absurd? Well, yes. But the painting is so delicate, so beautiful, so elaborate, that you don't really notice.

Tiepolo's next and last major assignment was in Spain: the ceiling of the Throne Room in Madrid's Royal Palace. The year 1762, when Tiepolo started this project, was long removed from 1492, when Christopher Columbus, another talented Italian employed by Spain, discovered the New World. But that's merely the beginning of the cycle of history, legend, and just plain propaganda portrayed on that ceiling.

A.G.E./Woodfin Camp

A.G.E./Woodfin Camp

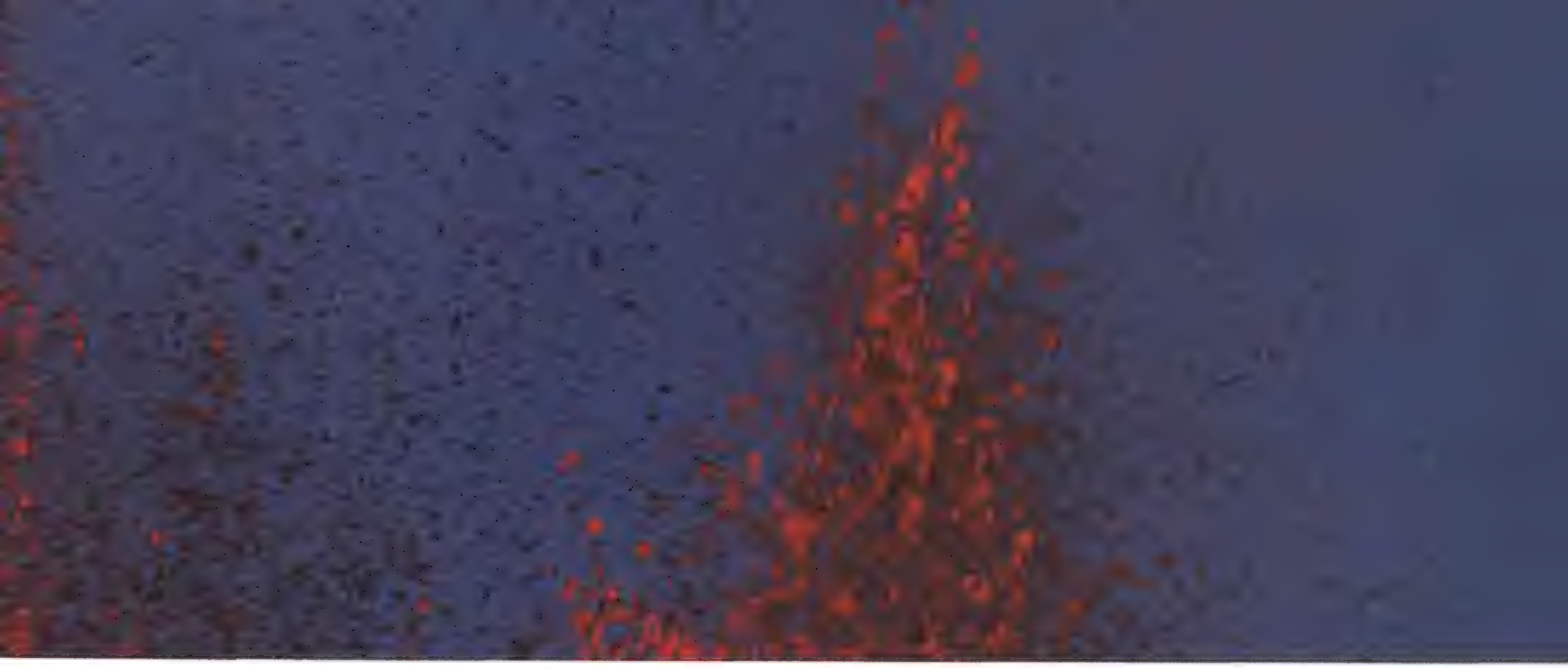
Not just another Royal Palace, Madrid's Palacio Real houses Tiepolo's last masterpiece (above).

Christopher Columbus, Neptune, and assorted cherubim and seraphim get in on the aerial action on the ceiling of the palace's Throne Room (left).

We see the royally proclaimed Admiral of the Ocean Sea being led by Neptune—the presence of pagan gods seems no more a problem for the "Most Catholic" monarchs of Spain than it was for the prince-archbishop of Würzburg. Columbus, however, does look a little irritated, perhaps thinking he could do the navigation himself, thank you. Banners flutter in breezes, cherubs and seraphs flutter through the air, and even those personages around the edge, who are more or less attached to earth, seem to float, barely touching down. In the topmost height of the painted ceiling, a circle of sky opens into infinity, around which jubilant angels swarm, with wings, wreaths, and trumpets.

Tiepolo died in Madrid in 1770. A mere 13 years after his death, the Montgolfier brothers arrived in Paris to show off their fascinating and instantly fashionable new device, the hot air balloon. No artist succeeded Tiepolo as the premier painter of flight, not even his sons. No one had to. Now, at last, human beings could fly themselves.

Did Giambattista Tiepolo know that flight would eventually grace the world? In a corner of that breathtaking ceiling over the grand staircase in Würzburg, Tiepolo left one of the great self-portraits in art history. It shows the artist, his eldest son behind him, staring out over a lovely stucco wreathed shell at the royal and religious aerial circus he has created. I used to think of him up there as the ultimate stage manager keeping a careful eye on the show. I now realize that, of course, it's Pat O'Brien watching, worried, as Jimmy Cagney takes off with the mail to St. Louis through the storm.



Essay

The Trouble with Air Traffic Control

Pilots need an accurate picture of the traffic around them. So where does our present system put that information?

On the ground.

By Thomas G. Foxworth

All of us middle-aged pilots who fly today's airliners were brought up on radar. And like poison in the well, the radarscope has had its effect on us. Ground-based radar has formed the basis of the nation's air traffic control system for so long that it has become a fixture, and most pilots—and certainly most people who travel by air—no longer question its role in air safety.

It was during the Battle of Britain that a new electronic technique called "radio detection and ranging"—radar—first made its appearance as a series of ugly steel towers along the chalk cliffs of the English coast. Though few knew their purpose, the towers were antennas that beamed out signals which, reflected back from swarms of approaching aircraft, gave England early warning of air raids. In the end, radar actually became a hero of the conflict. The romance was no doubt heightened by the work of serious young women in darkened rooms who interpreted squiggles of light—radar "echoes" from enemy bombers—on electronic screens and dispatched the victorious few in their Spitfires and Hurricanes.

But even before there was radar, there was air traffic control—ATC, as it's usually shortened. This past year, we celebrated the fiftieth birthday of a system that began with men in croupiers' eyeshades racking up cardboard strips to keep track of airliners. Pilots radioed in their positions at regular intervals, and the people on the ground moved the strips around on their boards. After World War II, air traffic control began to adopt radar, and a powerful combination was forged. Today the shirt-sleeved croupiers are still groundbound—traffic cops of the sky, seated on stools bolted to terra firma. Sometime in the dim past, we even went so far as to name them "controllers"—one of aviation's most unfortunate appellations.

Time has shown that a subtle and profound force has been at work, one I had not fully appreciated until I traded Navy flight gear for an airline uniform. British explorer Sir Edmund Hillary climbed Mount Everest because "it was there." Our ATC system has lurched along until it has become another national crisis—just because the ground-based radarscope "is there."

The system works acceptably when air traffic is widely dispersed. To understand why, just envision the difference between automobile traffic on the open highway and within the typical urban snarl: one flows easily, the other doesn't. Imagine drivers in a big city awaiting approval from some higher authority before they changed lanes or altered speed in response to changing traffic flows. Now expand that picture into three dimensions . . .

The problem becomes intolerable under the very conditions we need desperately to address: when the skies become congested, when harassed controllers on the ground can't talk fast enough to deal with the vast numbers of airplanes in one piece of the sky. Ironic, isn't it, that in the golden anniversary year of ATC, there's so much public outcry about its performance? Delays at congested hub airports are intolerable to travelers and cripplingly expensive to airlines. Five years after the controllers' strike, ATC is still understaffed while the number of flights surges. The Federal Aviation Administration imposes burdensome overtime on controllers, causing fatigue, discontent, and early retirement of its best people. The agency imposes an airspace structure and rules that would confound a math professor. And it becomes punitive to the entire industry to assuage a disturbed public.

Moreover, the problems with ATC make a mockery of deregulation; the system's capacity, not free market demand, is the de facto economic regulator. The usual solutions suggested are depressingly orthodox and unrealistic: build more airports, keep light airplanes out of major terminals, use bigger airliners and fewer flights. And while the debate stagnates, the radar empire is walled in.

I often ask myself, "Who is in control here?" I strap on a

piece of machinery as big as a building, hold in one hand more power than drives a battleship, and take you, me, and it up into the sky. And since my student pilot days, Federal Aviation Regulation 91.3, the first one you learn—the one that says, "the pilot in command is directly responsible for and is the final authority as to the operation of the aircraft"—has shrouded the aviation landscape like an overcast.

While we weren't paying sufficient attention, we pilots lost something precious. But it isn't as if there was no hint that it was coming. In my Navy days, we had already become slaves to surface radar. A radar room aboard my carrier issued commands, to which a young pilot could only answer, "Yessir." Today, more than two decades later, that same disembodied voice from afar still barks orders into my headset. Like young children, we have been conditioned to forgo the responsibility the regulation imposes upon us and reply, "Yessir."

But today we can break free from that. The space program and Atari geniuses who gave us $6.95 calculators and VCRs and a host of other electronic marvels have presented us with an alternative if only we can muster the will to grasp it. We can limit the croupiers on the ground to function as monitors, advisors, coordinators—nothing more. This, I submit, is their proper role.

The ATC system confronts a communication problem on many levels. At the working level, pilots and controllers are not communicating with each other—and they never really have. I don't mean the routine "have a nice day, sir" chit-chat that leavens dull days. I'm referring to the type of communication that's impossible in view of what both sides are given to work with.

While we weren't paying sufficient attention, we pilots lost something precious.

If I'm issued two dozen blind commands between the Deer Park and Canarsie navigation fixes on my way into New York's Kennedy International Airport, that's not communication, even if I "roger" every order. But if I were to be advised at Deer Park that a target visible on a cockpit display is the traffic I am to follow, that I should remain four miles behind it, that I'm then cleared to land—and while maneuvering my airplane to the runway I can continually monitor other traffic in my area on the cockpit display—*that's* communication.

The information I need clearly does not belong locked up in the ground-based radar system. It should be "uplinked" and displayed as a picture in my cockpit. Furthermore, if I may be so bold, it's foolish to perpetuate a system in which controllers call out the location of air traffic verbally—the antiquated "twelve o'clock" method. It's time-consuming, it's prone to error, and the traffic is usually never seen through bug-spotted windshields, clouds, or haze. The alternative is simple: *put the traffic picture in the cockpit.*

Right now, the FAA is wrestling with a much more primitive concept known collectively as "collision avoidance," which would provide a device and simulated voice in the cockpit to alert pilots when nearby aircraft get close enough to pose a collision threat. But these systems, which have been bandied about for years, have failed to be implemented because the concept suffers from a fundamental flaw: in order to work properly, all airspace users must be equipped with it. The more comprehensive picture I need would show all aircraft near me. The notion of such a cockpit traffic display is not new either, but in the past, it has been shelved because of its perceived inherent complexity and high development cost. Today's technology renders those two objections invalid.

The military has already adopted the philosophy of getting the needed information to pilots. How refreshing it was for me to ride in both an F-15 and F-18, two modern fighters, and experience firsthand the marvels of this electronic revolution. I operated systems that enable a single pilot to become a virtual battlefield commander in situations so complex that New York's airspace and its swarm of traffic is kindergarten by comparison. But even putting the information up there is not enough. The pilot must participate directly as an equal partner in decision-making.

Many airliners are already equipped with "flight management systems," which calculate the airplane's path over the ground and its desired vertical track—its altitude—along with the fourth dimension critical to pilots: time. These "4-D" navigation systems were successfully tested 15 years ago, and they have the computational power to allow pilots to deviate from a planned path because of traffic conflict, then get back on the assigned track and arrive at a metering "gate" in the sky at exactly the assigned second. Make the assignments and monitor my performance from the ground. But let me fly the assigned route—or let me tell ATC if I can't—and uplink the traffic picture so I can merge it with my navigation picture.

A question arises: can all users, big and small, participate? Let me hasten to say that light airplanes are not the problem; indeed, they may be part of the solution. They represent an alternative to airline travel, and they symbolize freedom of movement—a bedrock tenet of our society. But practicality dictates that we separate low-performance from high-performance aircraft—like bike paths and interstates. For smaller airplanes, radar and voice communication will continue in busy areas. Inexpensive but accurate navigation systems like Loran-C will enable small airplanes to pinpoint their position and bring them into the big picture. As more sophisticated airplanes get traffic-display equipment, there'll be more time for ATC coordinators to resolve the mix of traffic.

The capability to watch where we're going is here—it can be available to all of us at an affordable price. With the high-cost argument stripped away, continued resistance to an alternative to radar leads to the unavoidable conclusion that ground-based radar, as an institution, views any change as a threat to its existence. Unless we change that way of thinking, we'll remain hamstrung by a ground-based ATC system that operates like most other bureaucracies. We'll continue to genuflect to the radarscope. And if that radarscope continues to carry the ATC system's official seal of approval, we'll merely guarantee the day when the sky has become the limit.

Space Geniuses Wanted: Apply JPL

Mix a yen for astral adventure with some California creativity and you get the Jet Propulsion Laboratory, home to way-out thinkers and famous far-flying spacecraft.

By Stephan Wilkinson

Photographs by James Sugar/Black Star

Ask a dozen trivia nuts where U.S. rocketry got its start, and six will think of Robert Goddard's experiments in the 1920s in Massachusetts, a grown man with a chemistry set launching unguided firecrackers. Most of the others will likely vote for Wernher von Braun and his transplanted team of German technicians who Americanized the V-2. With luck, one space cadet might turn up who will mention Theodor von Kármán and his Jet Propulsion Laboratory (JPL). After all, what would a place with a name smacking of airplane research have to do with rockets?

A whole lot, it turns out. Space exploration began in earnest with the WAC Corporal, a 16-foot-tall beanpole of a rocket designed and produced for the military in the 1940s at that ill-named laboratory in Pasadena, California. And over the years some of the farthest-flying, most successful American spacecraft—the interplanetary probes such as Voyager and Viking—have come from that arrogant, academic, and joyously rebellious job shop for the National Aeronautics and Space Administration.

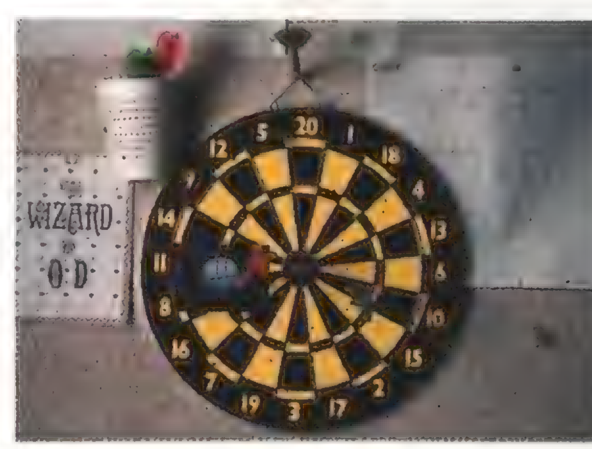
JPL's roots trace back to the late 1930s when von Kármán, then director of the California Institute of Technology's Guggenheim Aeronautical Laboratory, began fiddling around with things he shouldn't have been. Rather than investigating mainstream aeronautical matters such as airfoil behavior and engine design, the dapper Hungarian and his crew of graduate students wanted to really fly . . . with rockets. In a move that pleased both sides, von Kármán raised the money to transfer his smelly, dangerous experiments from the campus to a dry riverbed in the foothills northwest of the city.

The aspiring rocketeers proceeded to invent JATO, or "jet-assisted takeoff," for the U.S. Army Air Force. JATO's "assist" came from solid-fuel rockets strapped to the flanks of aircraft weighed down with fuel for long-range missions. Then came revelations late in World War II of dramatic rocketry advances in Germany, and von Kármán and his CalTech protégé Frank Malina proposed playing catch-up by establishing a "Jet Propulsion Laboratory" for the military. The Army Air Force wasn't interested. But the regular Army saw rockets as the artillery of the future and put up the money to open JPL. After NASA was formed in 1958, the Army got out of the space business and JPL went to work for NASA.

The sprawling Lab is unique among NASA's field centers in being part of a university—despite the ungainly birth, it remains a division of CalTech. "JPL is special," explains William McLaughlin, a bearded JPL engineer who looks as stern as an Amish elder but laughs much too heartily. "We're employees of CalTech, and technically we're contractors to NASA, not part of it. It gets fuzzed in our minds. We're poised in this equilibrium between the government and nongovernment worlds, and it works well for everybody."

Amidst the rich greenery of JPL's southern California campus, budding space scientists may be inspired to search for life on other planets.

JPL scientists often fantasize about far-out space transportation techniques. Dart propulsion, however, is one method that will never score a technological bull's eye.




OPERATIONS CHIEF

While JPLers may be known for their innovative thinking, they are not famous for their self-effacement. Says one scientist working on the Voyager program, "We're just a small part of NASA, but look at the returns we've gotten. When people talk about NASA's successes, they're almost always talking about *us*." A science coordinator has this to offer: "We don't feel we're part of 'the other NASA.' We're different. We've earned it." From a secretary: "*Exciting* people work here. We make history at the Lab every day."

Not everyone who's shared in the JPL experience believes it is quite *that* special. James Martin managed the Viking project for NASA's Langley Research Center and worked closely with people at JPL and other NASA field centers in his 12 years with the space agency (he's now a consultant to NASA). "JPL is not really better than other NASA centers," he says. And JPLers "are not as good as they think they are. They are good, but they're not supermen." In the end, though, even the skeptical Martin has to admit, "JPL had some excellent people in the Viking days, better than others, and still does."

License plates glimpsed in JPL's parking lot—in the land of MY ZCAR, where pride of ownership sometimes seems more common than pride in job—reflect the dedication of many JPL employees: tags include SPACFLYR, SPACE 1, COMETS, ANTENNAE, and JPL SETI (a reference to the ongoing search for extraterrestrial intelligence).

JPL director Lew Allen offers a more formal assessment of his charges: "These people believe their purpose is to explore the solar system, and that may create more enthusiasm than at other NASA centers." Allen, a former Air Force chief of staff, adds, "We are not bound by Civil Service restrictions, and that enables us to buy the brightest young people. It also obligates us to hire, promote, and fire on merit. There is no tenure here, so we don't have the stagnation in middle levels that exists in some Civil Service-staffed installations.

"It also grabs everybody's atten-

For Lab director Lew Allen, the mission control center is the next best thing to riding a space probe.

tion," Allen says, smiling broadly, "knowing their jobs are based solely on the work they do." Well, that's not quite true. Jobs may change for many at JPL because of the grounding of NASA's space shuttle; some projects may die or drag out for so long that employees get impatient and pick up stakes. "It worries us," Allen readily admits. "How long can you keep a scientist tied to a project without its producing any results? We're looking at a minimum three-year delay in the next launch of an interplanetary spacecraft."

For some people at the Lab, the current hiatus is a time when the aerospace industry beckons—"there are *always* jobs out there waiting for JPLers," says one engineer. For others it is a time of forced enthusiasm. And for many it is a time for wondering why their dreams and plans were hitched to a wagon they didn't ask for, an all-purpose manned space shuttle that is now complicating their lives immeasurably.

"A group of us, all young, all just out of college, all new at JPL, went to Florida together to see a Voyager launch in 1977," recalls Candy Hansen, a coordinator for the Voyager imaging team. "It was one of the last Titan-Centaur launches, and I remember we stood around and said it didn't seem like such a good idea for NASA to be putting all its eggs in one space-shuttle basket. The same group was together at the

time of the *Challenger* explosion, and we said to ourselves, 'Gee, even as kids we knew it was wrong.' "

But troubles on the launch pad aren't enough to squelch JPL's visionaries. "A common denominator here," says Mary Beth Murrill, a public information officer, "is that everybody used to watch 'Mr. Wizard' when they were kids. One of our people even found out where he lived and called him up recently and said, 'Thanks, Mr. Wizard. I'm at JPL because of you.' "

From planetary orbiters to star probers, the Pasadena facility is home to a diversity of people and projects.

The caller could well have been Randii Wessen, one of JPL's brightest young people, an openly enthusiastic 28-year-old space renaissance man who is a science coordinator for the Uranus mission of Voyager 2. "I'm a space weenie," he says, playing down his degrees in astronomy and aerospace engineering. "I came here because I wanted to visit all the planets."

When JPL people speak of "visiting" a planet, "flying on" a mission, or being "aboard" a spacecraft, they are serious, even though they're not talking about strapping themselves onto a rocket. "We do *go* to other worlds," Wessen explains, "even though we don't physically send ourselves." For JPL's space weenies, a fragile framework of microchips, antennas, and sensors such as Voyager 2 humming through interplanetary space is so real that they almost feel as though they were aboard. During Voyager 2's encounter with Saturn in 1981, "a local reporter kept referring to Voyager as being 'lame' because one of its sensors was frozen," says a JPL scientist. "We were just *incensed* when we read that man's articles. We get *very* close to the spacecraft. If anything ever happened to Voyager, it would be like a funeral around here."

In fact, says Wessen, "one of our scientists had a Viking funeral party a while ago at his home, with a model of the spacecraft put on a raft and floated in the swimming pool." Vikings 1 and 2 were a remarkable pair of orbiter-lander spacecraft that, among other things, collected data about the possibility of life on Mars—the conclusion was negative. The orbiters, built by JPL and designed to photograph the surface of the Red Planet for about three months, somehow kept working for years, relaying priceless data back to JPL's Deep Space Network control center in Pasadena. On July 25, 1978, the Viking 2 orbiter ran out of fuel for its attitude-control system and JPL switched it off for good. In 1980, on its 1,489th trip around Mars, the Viking 1 orbiter also ran out of gas and was put to sleep.

"What kind of people work here? Crazies," Wessen laughs. "I worked in the aerospace industry for two years, and the difference is night and day. At the company where I worked, my twin brother sent me a package containing a statue's hand and a card of questionable taste. The package wasn't addressed right, so it was opened in the mail room; security called me in for a talk. When he sent me a letter at JPL marked 'Top Secret, Classified' in Russian, it was de-

There's seldom a necktie or a briefcase in sight as JPLers spread out to pass around planetary gossip along with the mustard.

livered to me, no questions asked."

Such enthusiasm means that few people at JPL go home early. "You get people who will work all sorts of hours," says Bill McLaughlin, who manages the Voyager flight engineering office. "When you've got a mission going, you don't go home until it's over. It's a calling, not a job. No, no—a *calling*, not appalling." In fact, during planetary encounters JPL managers have trouble forcing team members to tear themselves away from the gripping video displays and go home to sleep.

Planetary encounters affect home life in other ways. "Some people schedule pregnancies around missions," says Voyager project scientist Ellis Miner. "Two births right here in our department intentionally came after the Jupiter and Saturn encounters, and now we've had our first birth following the Uranus encounter." (What's your sign? "Between Saturn and Uranus.")

Carolynn Young, who began her JPL career as a secretary and quickly moved into an administrative role with the Magellan project destined to map Venus, feels that JPL magic, too. "After the scientists here found out I was an amateur astronomer, it was a dream come true. They introduced me to other scientists, took me to parties where I'd meet astronomers.... I'd be grinning every morning as I got off the freeway and headed toward the Lab. My God, I'd think, I'm getting *paid* for this.

"There are a lot of people here who'd never make it in a corporate environment," Young continues. "This place is very unstructured."

An hour spent sitting in the Lab's cafeteria or campus-like central plaza confirms Young's assessment. Few people wear the required security badge, that dangling icon of government approval, and one senses that any busybody who asked to see one would risk a rude reply. There is an unhurried flow of people wearing everything from shorts and sandals to polyester suits and even the occasional sports jacket. Crutches and casts are a not-infrequent motif—the sure sign of a culture heavily into spring skiing, surfing, motorcycling, and triathlons.

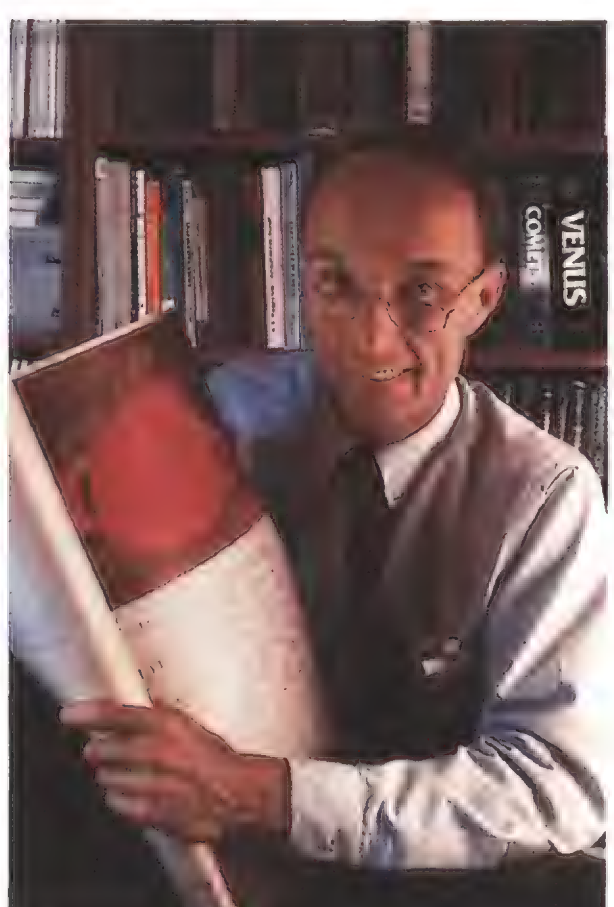
Two bright stars, Voyager coordinators Candy Hansen and Randii Wessen, hold an in-depth technical conference with a future mission mascot. "What kind of people work here?" asks Wessen. "Crazies."

Does JPL use any hiring clues to find its gifted young recruits, such as the rumored fascination of one major airline with pilot candidates who happen to be musicians? "If that's true, it's astute thinking on the part of the airline," says James Randolph, who leads advanced studies for JPL. "Some of the best people we have are musicians. The most creative employees are the ones who are doing outstanding things on the outside—skiing, flying their own aircraft, church work.... We've got more religious cults than any other NASA facility, I'm sure. People here really get into whatever they do."

As Candy Hansen of the Voyager team puts it, more directly, "It's a heterogeneous group. We have lots of nerdy engineers, but there are also a lot

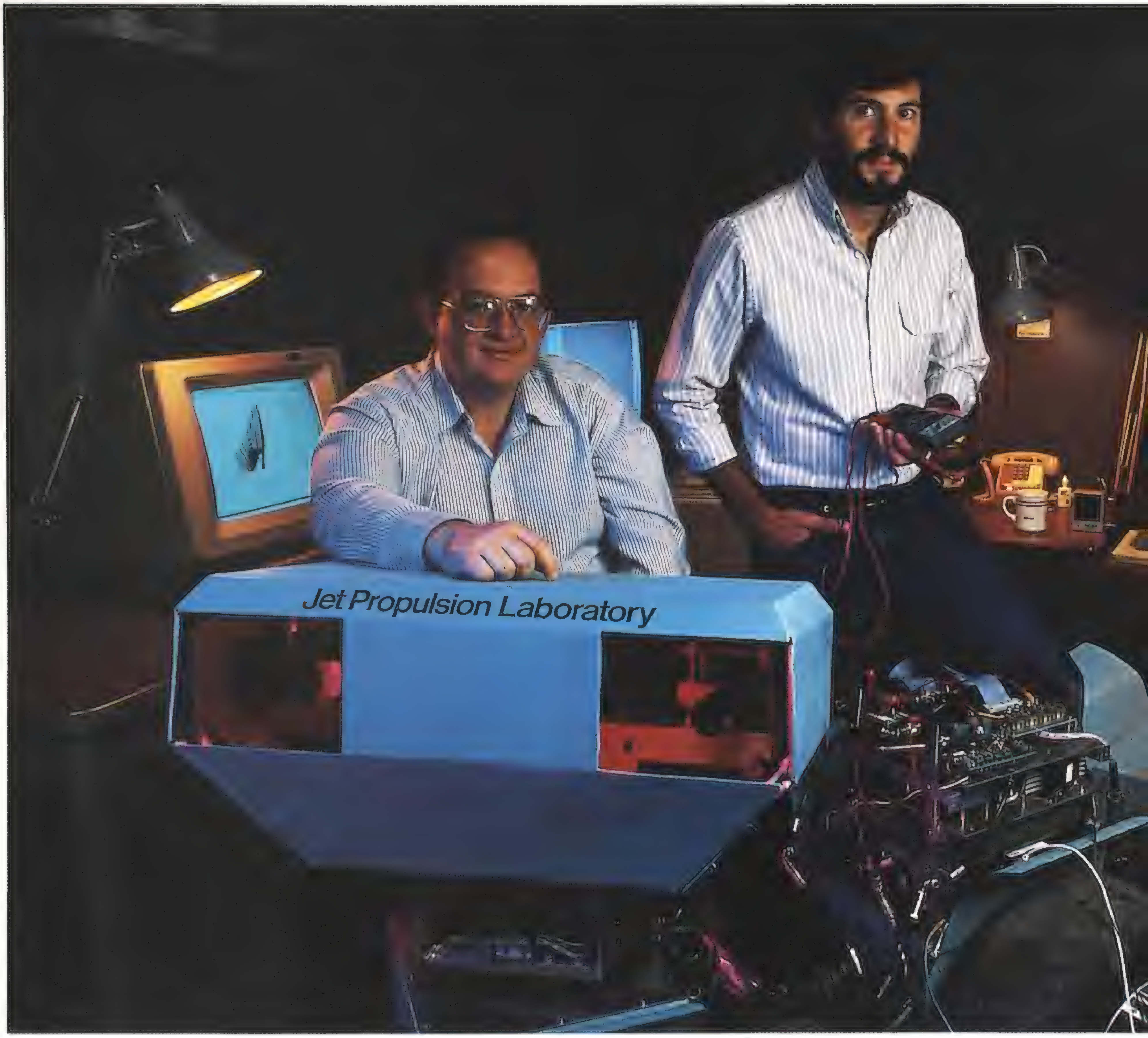
John Casani is the manager of JPL's Galileo project, an orbiter-and-probe duo set for a launch to Jupiter in the late 1990s. After a journey of two to four years, the spacecraft will study the giant planet's atmosphere, magnetic fields, and moons.

Andrew Ingersoll of the Voyager imaging team has viewed Jupiter, Saturn, and Uranus. Now the CalTech scientist awaits a peek at Neptune in 1989, the spacecraft's last stop in the solar system.



Interpreting Voyager data from Uranus is one job occupying David Stevenson, a professor of planetary science at CalTech. He's also working with a JPL group that has bounced signals off Saturn's moon Titan to learn about its surface composition.


FREDDIE



of people who don't fit that stereotype." Carolynn Young agrees: "The ideal JPLers are people who tend to be zealots. There are so few places where people can work and feed an interest in planetary exploration that young people who get jobs here can't believe their good fortune. As a result, the enthusiasm is overwhelming.

"But every once in a while," Young muses, "you'll see somebody who *doesn't* get excited and wonder why he's working at JPL."

One reason could be that he or she is on the military side. JPL, to the dismay of many of its scientists, is undertaking more and more contract work for the Department of Defense. "Management saw it as a good way to bring in bucks during the early 1980s, which was a really lean time for space exploration," says Randii Wessen. "There's a very vocal group, *not* in management, that doesn't want to do it. But if you've got things like a pointing system for the space telescope that's so accurate you could put it in Los Angeles and keep it aimed at either edge of a nickel in San

Engineers Jonathan Cameron, Brian Cooper, and Robert Salo (left to right) specialize in robotics. Their current favorite is a working prototype of a Mars rover. They want to know if the vehicle, designed as a lunar explorer in the 1960s, can fetch Martian soil for return to Earth.

JPL Sampler

For more than 40 years California dreamers at the Jet Propulsion Laboratory have been churning out innovative rockets and spacecraft. Here are some milestones:

1945 The first manmade object to rise above Earth's atmosphere, the WAC Corporal rocket reaches a record altitude of 43.5 miles on September 26.

1958 On January 31, the Army launches the JPL-built Explorer 1, America's first orbiting satellite. Explorers 1, 3, and 4 (2 and 5 failed to achieve orbit) collect surprising data on cosmic radiation that reveal the existence of the Van Allen belts that circle the Earth and sometimes affect electronic communications.

1959 Though beaten by the Soviet Union's Luna 1, Pioneer 4 becomes the first U.S. spacecraft to escape Earth's gravity. Launched March 3, it comes within 35,500 miles of the moon, but not close enough to qualify as a lunar flyby.

1962 For the first time since Sputnik, the United States beats the Soviet Union in space: Mariner 2, sent on its way August 27, becomes the world's first successful planetary probe, flying past Venus and returning data that radically change our view of that cloud-shrouded planet.

1964 Breaking a string of Ranger failures, Ranger 7, launched on July 28, returns 4,300 photographs of the moon—the first close-ups—before crashing into the lunar surface. Mars is also visited by Mariner 4, which takes off for a flyby mission on November 28 and returns the first pictures of the planet—just 21 of them—eight months later.

1965 The world watches on March 24 as Ranger 9 transmits lunar images on live television before plummeting to its destruction on the moon.

1966 Achieving history's first soft landing on another celestial body, Surveyor 1 eases down onto the moon, allaying scientists' fears that future astronauts would sink into a sea of lunar dust.

1967 In November, Surveyor 6 becomes the first spacecraft to make a local lunar flight, traveling 8.2 feet over the moon's surface.

1969 For the first time, the United States launches two missions to the same planet back to back: Mariners 6 and 7 start toward Mars on February 24 and March 27. In another first, flight controllers reprogram Mariner 7 in midflight based on information relayed by its slightly-in-the-lead sister craft.

1973 NASA launches the world's first multi-planet mission, Mariner 10, to Venus and Mercury. Thus ends JPL's series of reconnaissance flights to the planets of the inner solar system.

Jet Propulsion Laboratory

Work that began in the 1930s for JPL pioneer Frank Malina reaped remarkable rewards in the 1940s when the WAC Corporal rocket helped usher in America's space program.

1976 The first devices to soft-land on another planet are carried to Mars on board Vikings 1 and 2. The landers—designed and built by Martin Marietta—relay data that virtually confirm the answer to a long-standing question: there is no life on Mars.

1977 The first grand tour of the outer planets begins when NASA launches Voyagers 1 and 2.

1979 Jupiter is the Voyagers' first observation stop, and for the first time scientists see active extraterrestrial volcanoes, on the Jovian moon Io.

1980 As it flies by Saturn, Voyager 1 discovers three new moons and takes a close look at an old one, Titan, finding that its atmosphere is loaded with nitrogen, a primary requirement for life. The spacecraft then starts on its way out of the planets' orbital plane and into the depths of space.

1981 Reaching Saturn, Voyager 2 finds more new moons plus moonlets in the planet's rings. Voyagers 1 and 2 ultimately reveal a total of 20 moons.

1986 An encounter with Uranus is next on Voyager 2's agenda. The spacecraft sends back pictures of newly discovered moons and reports that Uranus, like Jupiter and Saturn, emits electroglow—solar energy somehow amplified as it is radiated off the planets' surface.

—*Stephan Wilkinson*

After the Magellan space probe maps Venus in the next decade, Carolynn Young and project manager John Gerpheide will better understand the cloud-shrouded planet's surface, which is bone-dry and oven-hot.

Francisco, the military applications are fairly obvious."

JPL's military involvement is still quiet enough that off-limits signs are rare and uniforms are not considered stylish. But with NASA's planetary exploration program grounded for the next few years, JPL has little choice but to do some work for the Department of Defense if it intends to keep its team intact. So, like a violinist playing street gigs between concerts, JPL uses the military contracts to keep its hand limber. "The things the Department of Defense asks us to do are very advanced projects of the sort that NASA had not been able to support," says Lew Allen. "We hope to apply what we learn to future NASA work." He adds that under JPL's contract with NASA, no more than 25 percent of its staff may work on non-NASA contracts at a given time, although the dollar value of current defense contracts totals 29 percent of the Lab's $820 million budget.

JPL's future is not filled with Star-Wars weaponry, certainly. But for its scientists and engineers, the space program slowdown is a depressing time. Consider what's happened to the Lab's most important new project: Galileo. The complex 2.75-ton spacecraft, designed to orbit Jupiter and send a probe to its surface, was to have been carried aloft on the space shuttle last May and then flung toward the giant planet by a new Centaur booster. But after the *Challenger* accident, NASA cancelled the Centaur program because of safety concerns, burdening mission planners with the task of figuring out how else Galileo might reach its destination.

Another major JPL mission that has been grounded is Magellan, the sophisticated radar mapper that will chart the surface of Venus through the planet's thick cover of poisonous sulfuric acid and carbon dioxide clouds. "Both Magellan and Galileo will go up late in the decade," says Ellis Miner, "but then we'll be launching spacecraft that are already ten years old.

"If the slowdown really means marking time for several more years, some people might leave. But where could they go that would give them anything like the excitement and opportunities they have here?" Miner says.

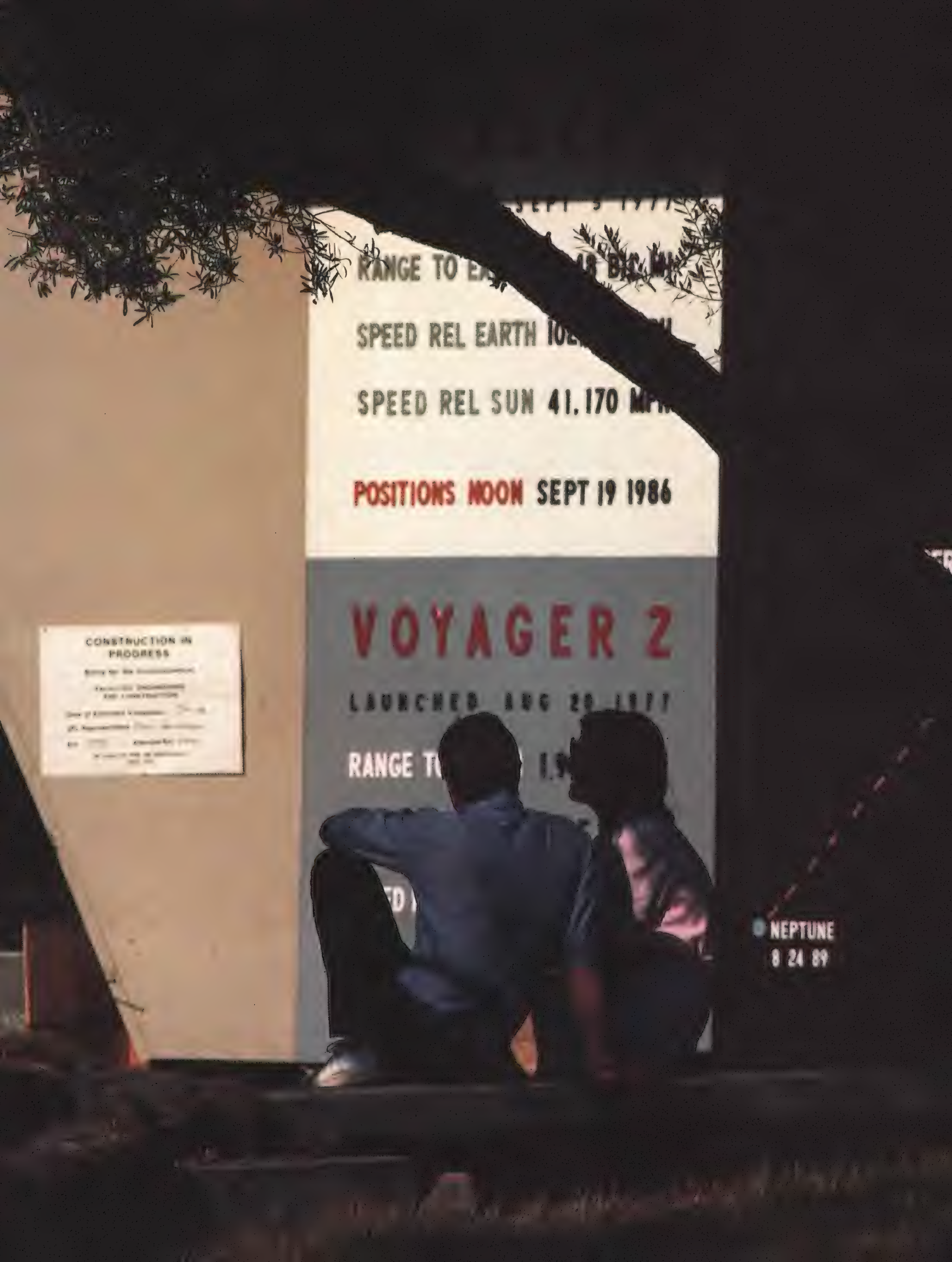
Ah, but there's one brave, faithful, weary, indomitable—and, yes, lame—traveler out there plugging away for JPL. Voyager Lives . . . though much of the world has forgotten that the plucky little adventurer is still chugging along following its encounter last January with Uranus. Over the last ten years, at the piddling cost of 20 cents per year per citizen, Voyager 2 has increased humankind's knowledge of the planets somewhere between a hundred-fold and a thousand-fold.

In the summer of 1989, Voyager 2 will become the first Earthly artifact ever to encounter Neptune, and scientists are awaiting that flyby anxiously. Does Neptune have winds? Cloud features? Moons that we don't know about? Little is known about the huge planet, but Voyager will fix that. And when it finally coasts past Neptune and floats off into infinity, there will be another happy-sad funeral party in Pasadena.

What then? Jim Randolph gives a hint. "There are only so many planets and moons in our solar system, and we've kind of looked at most of them, but our thoughts continually wander as far away as possible. We're working on new propulsion technology for faster travel to the outer planets and then the stars, using a nuclear reactor to power electric engines." JPLers hope such newfangled technology will drive a spacecraft called TAU, for Thousand Astronomical Units—an astronomical unit being the distance from Earth to the sun, about 93 million miles. Power and communications systems to support such a long-distance mission are still in the works, however.

"Beyond that comes fusion propulsion," he adds, "and then antimatter propulsion. Yeah, two or three people here are working on exactly that." Why are these people moving in such strange directions? "It's a fundamental human desire to explore," Randolph muses. Around other stars there may be planets, and on those planets there may be, let's say, things worth checking out. JPL's explorers want to go.

Even when JPL's self-proclaimed "space weenies" try to steal a few moments from the fray, reminders of work are not far away.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Homemade Satellites

Fritz Mendell

Twenty-five years ago, the amateur radio satellite program moved from a California garage into orbit—thanks to some home-built hardware and hard-core hams.

By Nancy Shute

From the basement of a white clapboard house in Salina, Kansas, the call goes out: "W-Zero-C-Y, W-Zero-C-Y." Jim McKim is talking to satellites again. As usual, the satellites are talking back.

Big deal, you say, in an age when satellites regularly transmit Elvis Presley movies around the world. But McKim is searching the heavens for OSCAR 10, a satellite designed, built, and operated not by behemoths of the aerospace industry but by amateurs, whose qualifications are a love of satellite communications technology and pooled technical savvy. For 25 years this December, radio amateurs like McKim have been running a homegrown space program, at almost no cost and with remarkable success.

"That's OSCAR 9 or 11—hear the Doppler shift?" says McKim, a wire-thin 71-year-old with a bristling gray flattop, as a squeal changes in pitch. He twiddles the dial on his receiver and the radio frequency band plays an electronic symphony of bleeps and blips. "There's a lot of spurious emissions this morning—a lot more than I normally hear." He homes in on a faint *rrr-rrr-rrr* among the crackling cacophony. "That's OSCAR 10. I can hear the spin modulation as that bent antenna comes by."

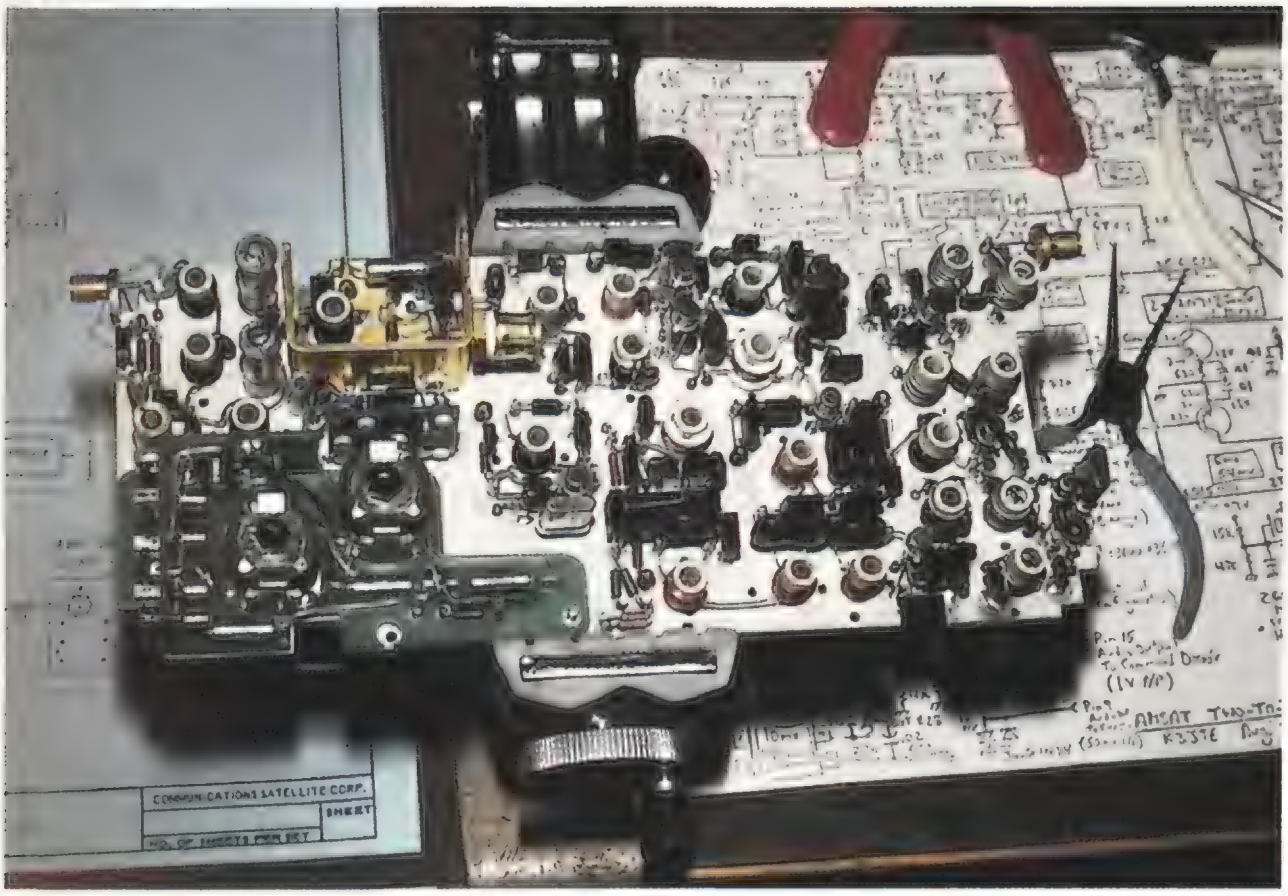
McKim taps out a Morse code "test" on a telegraph key, but the satellite doesn't reply. Undaunted, he puffs on his pipe and leans over to push a button on the fearsome array of hardware surrounding his immaculate desk. The button adjusts a roof-mounted antenna aimed at a point five degrees above the horizon, aligned with OSCAR 10's 2,368th orbit as outlined on a map of the continents glowing on the computer screen. McKim, who tracked satellites by hand-written calculation in the days before personal computers, appreciates their assistance. He patiently re-transmits the test signal and this time the reply clicks out almost instantaneously on the speaker, having completed its sprint from Salina to OSCAR 10 and back. Communications link established, McKim begins tuning in users and is soon chatting with other satellite fans in New Mexico, Canada, and California.

OSCAR 10 is just one of six operational amateur satellites hailing from the United States, West Germany, Japan, England, and the Soviet Union, all of which exist for the free use of radio amateurs everywhere, an ad hoc network of an estimated one million "hams" (the origin of the term is lost to history) dedicated to maintaining global communications in time of trauma, as during last year's earthquake in Mexico, and for discussing the banalities of everyday life.

McKim, a retired electronics merchant who received his first amateur radio license in 1933, is one of the acknowledged deans of amateur satellite users. Since he first got "on the satellite" in 1972, McKim has made contact with hams in every state and in 69 countries, and he can reel off the names of electronic companions with a fondness nurtured over the years. "That's Niki in New Mexico," he says as he picks up a woman's voice detailing the weather. "She's talking to Doug in Tasmania." Because only a few thousand of the world's radio amateurs use the satel-

Jim McKim, an amateur radio buff for 50 years and a satellite user for 15, now tracks his "birds" by computer instead of tedious work with a pencil.

Dick Daniels



Dick Daniels built the transponders for several OSCARs, but lost one when he put it in the oven to "cure" and promptly forgot about it.

lites, McKim says, "you can really become good friends."

McKim isn't alone in feeling a special affection for satellite communications over regular amateur radio, which bounces its transmissions off an upper atmospheric layer called the ionosphere. Again and again, satellite users note proudly that they had to make all the hardware themselves until recently, that it takes finesse and mathematical expertise to track a satellite, and that theirs is an elite corps of celestial conversationalists with manners more rarified than those of the terrestrial ham. McKim keeps a special file marked "satellite" for the traditional reply cards used to confirm amateur radio contacts, many of them decorated with meticulously hand-drawn "birds," industry slang for satellites.

"I'll admit to being a snob," says Eric Rosenberg, a 30-year-old user in Harrisburg, Pennsylvania, whose satellite contacts have become valued friends in his many moves around the country as a public-television producer. "The group involved in amateur satellites is a cut above the ordinary. The people I've met are from all walks of life but have a common interest in space technology." Rosenberg laughs, and adds, "It's my one nerdish pleasure."

Nerdish, perhaps. How about obsessive? Rosenberg says he tries to keep his sessions down to once or twice a week, but a hard-core user like McKim admits to being on the satellite up to eight hours a day, not to mention the hours spent mailing tracking software to neophytes and hosting a weekly amateur-satellite talk show as he has almost every Tuesday night for the last 11 years. McKim even keeps his watch on Universal Time Coordinated, the new name for Greenwich Mean Time. His wife, Dolores, just laughs when asked if she's worried about a grown man spending the better part of his waking hours hunched over a transmitter in the corner of the basement. "At least I know where he is."

McKim's immersion in space communications goes back way before the first amateur satellite was launched—back, in fact, to Sputnik 1 and the beginning of the space race. At 4 a.m. on October 5, 1957, McKim got a call from the Associated Press, which had heard that he, like thousands of radio amateurs and shortwave listeners, had equipment that could pick up the radio beacon on the just-launched Soviet satellite (transmitting on the 20-megahertz band). Within an hour, McKim had tuned in to Sputnik beeping continuously in orbit. He treasures the tape he made of the beginning of the space age, as well as his collection of the voices of earlier OSCARs, which he plays as proudly as a grandfather with a family videotape.

Sputnik's siren call lured a good many radio amateurs into musing about space. Ever since Guglielmo Marconi completed the first transatlantic radio communication in 1901, long-distance transmissions have been plagued by disturbances and blackouts caused by variations in the Earth's atmosphere and the unsolved rhyme or reason of sunspot cycles—all of which contribute to the radio-wave phenomenon called "skip," the reason you sometimes receive a Chicago AM station when you've tuned in New York. Scientists and engineers had determined that because satellite radio communication wouldn't rely on the fickle ionosphere to bounce radio waves to faraway stations, it would be almost foolproof. Still, when ham Don Stoner suggested in 1959 that radio amateurs launch their own satellite, many of his brethren reacted as if he had a transistor loose.

However, other hams took the immodest proposal as a personal challenge. The ranks of radio amateurs are heavy with scientists and engineers whose notion of a good time is to wrestle with a nice, knotty algorithm. Visions of a home-built satellite set them to gnawing the ends of their pencils into the wee hours. In 1960, a group of hams in Sunnyvale, California, many of whom worked in the infant aerospace industry, formed Project OSCAR, which stood for Orbiting Satellite Carrying Amateur Radio. Their mission: to put the first amateur communications satellite in orbit.

They soon realized that a true communications satellite was more than they could get off the ground at the moment. Instead, they took a flyer on creating a Sputnik-like satellite with a beacon that would relay data on the satellite's temperature by changing the speed of its message transmission. Lance Ginner, who was then a 22-year-old engineer at Lockheed, built most of OSCAR 1 in his garage, laboring every spare moment for four months. He laughs now at the presumptuousness of the effort. "Satellites were a very new thing. If we'd thought about it too much, we probably wouldn't have done it."

OSCAR 1 was no bigger than a bread box, and in fact looked suspiciously like one: a ten-pound sheet-metal box with a stubby antenna poking from its midsection. Construction methods were decidedly low-tech: the satellite was tested for resistance to the temperature variations it would encounter in space by

stuffing it in a cardboard box with a fan at one end and a heater at the other. Ginner worried more about setting the cardboard on fire than about the survival of OSCAR 1, which passed the test with flying colors.

However, making OSCAR 1 was only half the battle. Drawing on business connections with the military and on deep stores of moxie, the Oscarites cajoled the Air Force into piggybacking their electronic bread box on a Discoverer satellite launch. The request wasn't so very far-fetched: most launch vehicles have more payload capacity than is needed to loft a satellite, and older rockets were usually ballasted with dead weight. Surely OSCAR 1 could serve as dead weight as well as anything else.

Lance Ginner labored over OSCAR 1 in his garage in California between shifts at the Lockheed Corporation.

Project OSCAR

On December 12, 1961, exactly 60 years after Marconi's transmission, a Thor-Agena roared off the pad at Vandenberg Air Force Base in California, carrying Discoverer 36 and OSCAR 1 into space. The satellite spent 22 days in orbit, transmitting the Morse code for "hi" before its batteries died.

"It just goes to show what people can do when they get fired up," Ginner says now. "Anything is possible."

Euphoric, the Oscarites dove into designing and constructing OSCAR 2, essentially a duplicate of OSCAR 1, which was launched six months later. They achieved a major jump in capability in 1965 with the launch of their first true communications satellite, OSCAR 3. The bird sported the low-cost design that was becoming an OSCAR trademark: two springs protruded from the ungainly box to push it away from the launch vehicle, and four lengths of metal carpenter's rule served as antennas. But OSCAR 3 also carried the first amateur radio satellite transponder, a device that listens for signals on one band of frequencies, amplifies them, and retransmits them back to Earth on another. By tracking the times when the satellite rose above their horizon, hams could transmit to OSCAR 3 on a direct line of sight, and the satellite would transmit back to Earth via the transponder, its line-of-sight transmission area being far larger than that of any terrestrial station.

OSCAR 4's launch later in 1965 met with less success when an upper-stage failure of an Air Force Titan rocket marooned the satellite in an erratic orbit that made linking up from the Earth extremely difficult. Still, during its short lifetime, hams managed to use OSCAR 4 to establish the first American-Soviet satellite communication.

Undaunted, students at the University of Melbourne in Australia began building Australis-OSCAR 5. But when the satellite was delivered to California, local Oscarites discovered that their Air Force launch contacts had been transferred, promoted, or reassigned. They couldn't drum up a launch, and the newest OSCAR gathered cobwebs in Lance Ginner's garage.

Enter Jan King. In 1970, King had just finished college in the midwest and had moved to Washington, D.C., to work at the National Aeronautics and Space Administration's nearby Goddard Space Flight Center. He had tracked earlier OSCARs during high school and had done science projects writing computer programs for OSCAR orbits on IBM punch cards. "It was something practical and exciting to do with mathematics," King recalls.

The young physicist soon found his leisure hours devoted to far greater excitement as vice president of engineering for the Radio Amateur Satellite Corporation, AMSAT, a nonprofit organization newly minted by amateurs in the Washington, D.C., area to assist the California group. With typical OSCAR aplomb, King and his cronies had Australis-OSCAR 5 shipped east. They vacuumed out its cobwebs, replaced a few perishable electronic components, and got it launched early in 1970 on a NASA Thor-Delta rocket carrying a meteorological satellite.

Infused with new blood, the OSCAR program moved from its garage origins into an era of increasing technological complexity and innovative design. At long sessions over pizza and beer at a scruffy Maryland roadhouse, a dozen or so core AMSAT members hammered out the design for a series of sophisticated OSCAR satellites.

Dick Daniels was one of the roadhouse gang who loved space and the hardware related to it. "I really get a kick out of knowing something I had my hands on is in space," Daniels says. "It's an act of creation." In true OSCAR style, he built systems for four of the satellites on the pool table in the basement of his home in Arlington, Virginia, once frying an epoxied and nearly com-

When two of OSCAR 10's creators, Daniels and Wolfgang Mueller of West Germany, loaded its kick motor with toxic propellants at the Ariane launch facility in French Guiana, they reported "things got pretty intense."

AMSAT-DL/Wilfried Gladisch

pleted transponder when he accidently left it curing in the oven while he set off for a concert. "I remembered I'd left the oven on at the same instant someone came down the aisle looking for me," he recalls. "The kids had smelled something burning." The oven survived, but the hundreds of hours of work on the circuit board were for naught.

At 54, Daniels, a NASA bureaucrat with the soul of a scientist, cheerfully admits to being infatuated with what he calls the "living personality" of satellite hardware. The infatuation has twice driven him to spend weeks in French Guiana at great expense and lost vacation time, preparing AMSAT satellites for launch on the European Space Agency's Ariane rockets. In 1980, wired like a condemned man against the risk of static igniting the propellant, he prepared the satellite's solid-fuel kick mo-

tor for the May 23 launch. However, the launch resulted in the OSCAR program's first total disaster when the Ariane rocket suffered a first-stage engine failure moments after liftoff.

Daniels and the team didn't mourn for long. "We turned around and built another." In 1983, he was back in French Guiana, this time resembling Linus in his overpadded snowsuit. Daniels' special clothing protected him from the

Dick Daniels

highly toxic propellants being loaded into AMSAT's first liquid-fuel motor, donated by the German aerospace firm Messerschmitt-Boelkow-Blohm and valued at $2 million. "That got pretty intense," he acknowledges. Daniels and crew were rewarded with the launch of OSCAR 10 on June 16.

AMSAT enthusiasts in the United States are not alone in their devotion. Ten countries are now involved in OSCAR design and construction, including West Germany, Great Britain, Japan, Hungary, and Canada. The satellites are still sheet-metal boxes, but today's triangular three-armed creations, weighing in at up to 250 pounds, bear little resemblance to the original bread box. The latest creation, Phase IIIC (the satellites are christened OSCAR only after reaching orbit), is being produced by a U.S.-West German team. It carries four transponders, an onboard "housekeeping" computer, an attitude control system using Earth and sun orientation sensors, ten antennas, and a ground-controlled kick motor for fine-tuning the orbit path once the satellite is aloft.

Although OSCAR 1 cost only $65 in parts, the increasing design complexity has driven builders to devote more and more time to begging for donated hardware from industry and funding from organizations and individuals, such as Jordan's King Hussein, an avid ham. Ironically, a mishap has also paid off in the form of insurance claims for OSCAR

AMSAT's latest satellites are increasingly sophisticated, but are still built in spare rooms in spare time.

10, which, although operational, was stranded in too low an orbit when the propulsion system failed to ignite for a second burn. Phase IIIC is insured for $650,000, which its builders say is a fraction of its true value on the commercial satellite market.

Jan King, who has become legendary for meticulous production standards and his talent for coaxing highly intelligent and idiosyncratic volunteers into working together harmoniously, laments that most of his time is now spent on such details as wrestling export licenses from the U. S. State Department. "We consider this a travesty, but our satellite, as are all others, is considered an article of war," King explains ruefully. "We had to become a munitions dealer. You can imagine how happy *that* made us."

The current crisis in the launch industry has also affected AMSAT: the Ariane launch of Phase IIIC, originally scheduled for the fall of 1986, has been put on hold until next year due to a launch failure in May. The amateurs take the delay with equanimity, saying it gives them more time to tinker with the design of the satellite's onboard computer and hone their launch-procurement techniques. "It's always been a ticklish process to get launch space,"

Sarah Leen

Students in Philadelphia have talked with an astronaut in orbit via satellite and now want to build their own.

King says. "It's made us lean and mean. It's exciting to stand up in front of a NASA program manager who says, 'You're not going on *my* launch vehicle,' and say, 'Yes, I am.' The trick is in not taking 'no' for an answer."

Many in the AMSAT inner circle say that today's organization, with 6,000 members worldwide, can do more than just talk. Some see amateur satellites as the perfect vehicle to rekindle students' fascination with space technology. Others see them as a way to revitalize the amateur radio community, which has suffered from a lack of interest by youngsters, enticed by computers, who grow up to be software designers instead of engineers and physicists.

Howard Ziserman, a 34-year-old chemistry graduate student, first met OSCAR when he deciphered Australis-OSCAR 5's telemetry transmissions as a student at Northeast High School in Philadelphia. He went back to his alma mater 14 years later and established a program to teach students how to use the satellites. "The hardest thing for me to put across to the kids is that you don't just push a button," Ziserman says. "You have to use your noggin—you have to sweat."

Six of Ziserman's protégés now have amateur radio licenses, and in 1985 they set up a mobile unit at the Franklin Institute Science Museum in Philadelphia and made voice contact with astronaut Tony England in orbit aboard the shuttle. "One of the kids got so good at tracking the shuttle that by the second day he was pointing the antenna not by computer but by ear, by the shift in tones created by the Doppler effect," Ziserman says. Now the students want to build their own satellite.

Back in McKim's basement, at 9 p.m. on Tuesday, August 5, McKim is listening for AMSAT president Vern Riportello in New York to hand off the weekly AMSAT broadcast, which relies on ionospheric transmissions rather than the satellites. "W-Zero-C-Y, net control for the mid-America section this evening," he murmurs into the microphone. "Static's a little high here, but we've been copying Rip pretty well, so let's get started with sign-ins." Ghostly voices whisper call letters, and McKim greets each with the savoir-faire of a prairie Phil Donahue. "W-5-I-U, good evening, Keith."

Big news on the network: JAMSAT, the Japanese affiliate, is poised to launch its first amateur satellite aboard the new H-1 launcher, and AMSAT is ready with daily advisories and real-time coverage that would make Walter Cronkite proud. Tonight, the hams are full of questions: what are the orbital parameters that, when fed into their home computers, will allow them to track the new bird on its first pass overhead? When will the transponders be usable? How is the health of OSCAR 10, whose onboard computer failed recently?

By the following Tuesday, August 12, the AMSAT network is activated: one ham in Tokyo is ready to relay the exact time of launch and another is at a NASA tracking station in Chile to report on the final-stage separation. After a 14-minute delay, the launch goes off flawlessly, and six hours later, at 8:48 p.m. Central time, McKim picks up the satellite's beacon on its first pass some 900 miles above the United States. There's scant time to celebrate: the bands are crackling with hams anxious to get parameters adjusted for the launch delay. Along the flight path, satellite fans like Eric Rosenberg and Howard Ziserman are waiting for the first signs of life from Fuji OSCAR 12. They too tune in the bird on its maiden orbit, and once again, like those first days in Lance Ginner's garage 25 years ago, anything seems possible.

It illuminates our night skies, times our tides, and inspires poets and lovers. It dances with the Earth in an intimate tango that has given us the month, a sense of the orderly cycles of nature, and those spectacular irregular happenings, eclipses of the sun. We've gazed at it, lased at it, and landed on it. Twelve astronauts have walked its ancient surface. Samples sit in museums and laboratories, still yielding clues to secrets of the solar system.

Yet only recently, reluctantly, did the moon begin to reveal its most fundamental secret to us. With a seeming suddenness that no one could have predicted, planetary scientists have now reached some tentative agreement on how the moon was created.

The moon, they think, was born out of cataclysm.

In the murky beginnings of the solar system, when the would-be inner planets were still partly molten, an object roughly the size of Mars collided with the Earth. The intruder struck at a speed greater than 20,000 mph, impacting at an oblique angle. There was a gigantic explosion and the outer layers of the reckless "planetesimal" disintegrated, the rocky material at least partially vaporizing.

The foreign material—perhaps along with a sizable vaporized chunk of the Earth's outer layer, or mantle—was ejected rapidly into space. Some of the material went high enough to achieve orbit, forming a glowing belt around the Earth. Within an hour, the vapors began to cool and condense into small solid particles. And over a period of only a few hundred or a few thousand years—a cosmic blink—these gravel-like particles coalesced and formed the primitive moon.

This, in briefest sketch, is the scenario of what's called the giant impact hypothesis. "It's a very promising idea," says Alan P. Boss, a physicist in the Department of Terrestrial Magnetism at the Carnegie Institution of Washington. "I'd say it is now the favorite hypothesis for the origin of the moon."

"It's the biggest catastrophe of all," says H. Jay Melosh of the University of Arizona's Lunar and Planetary Laboratory, who has been modeling the event by computer. "It's a whole scale bigger than the impact of an asteroid or some other object that some scientists now say was responsible for the death of the dinosaurs 65 million years ago."

Still, most planetary scientists want to play it safe, remaining cautious and not overstating the case. The giant impact hypothesis is new, and unforeseen technical problems could arise. But as Boss wrote recently in *Science* magazine, the prestigious journal of the American Association for the Advancement of Science, "It now appears that the moon was formed after a giant impact of a roughly Mars-size body on the proto-earth. . . . Much of the detailed physics and chemistry associated with the giant impact hypothesis is yet to be studied, but the exploratory work completed so far has not revealed any fatal flaws in the hypothesis."

The origin of the moon was supposed to be old hat by now: one of the main scientific goals of the Apollo lunar landings was to lay that hoary question to rest. But several trips and 843 pounds of moon rocks later, there were still more questions than answers. And the giant impact theory wasn't even seriously in the running—until now.

"The whole idea that the lunar formation process may have been more catastrophic than thought has become respectable," says William K. Hartmann of the Planetary Science Institute in Tucson, Arizona. "My sense at the moment is that the more work that is done, the more favorable this idea is looking." Hartmann, a versatile planetary scientist who paints far-off scenes of the solar system and writes popular astronomy articles in his spare time, is one of the originators of the giant impact hypothesis. The other is Alastair G.W. Cameron of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. Long involved in studying the history of the solar system, he is a respected astrophysicist and a former chairman of the National Academy of Sciences' Space Sciences Board.

The irony is that their original proposals were published more than a decade ago, independently, and mostly ignored—a fate shared by many scientific hypotheses. Occasionally, a fresh look is taken, and an idea that seemed outlandish or bizarre, when combined with new tools and studies, is seen in a new—and more positive—perspective. Fortunately for science, this is what happened to the giant impact idea.

Earth and the other inner planets are thought to have formed approximately 4.6 billion years ago by gravitational

MOON? BOOM!

The birthday party lasted less than an hour, as a reckless planetary wanderer smacked the Earth and splashed material into space that would eventually form the moon.

By Kendrick Frazier

While waiting a decade for his theory of how the moon was born to catch on, planetary scientist William Hartmann painted that cataclysmic blast from the past.

accretion: planetesimals—"little planets"—drew together to form bigger planets. In 1974 Hartmann and colleague Donald R. Davis calculated the probable size of planetesimals that would likely have been zipping around the early Earth's neighborhood. The numbers confirmed that there should have been plenty of good-sized objects. "We could easily imagine getting bodies as big as Mars," recalls Hartmann. "Thus if one of them was essentially swept up by the Earth and collided with it, you could get material shot into orbit to form the moon."

Any successful theory for the origin of the moon must explain several peculiarities. One is the anomalously large "angular momentum" of the Earth-moon system, a combination of Earth's rotation rate and the moon's revolution about it. (A familiar example of angular momentum is the figure skater who spins slowly when her arms are extended and spins ever faster as she draws her arms closer to her body.) The problem is that the Earth, in effect, is spinning faster than it should. But planets don't start spinning faster by themselves—they need a shot of energy from some outside source.

Another peculiarity is that the moon contains very little iron, while the Earth's core is iron-rich; the moon's density turns out to be the same as the density of Earth's rocky mantle. The moon also is markedly lacking in volatile materials (molecules such as water and metals that are easily vaporized) compared with Earth and other objects in the solar system.

Hartmann and Davis recognized that a moon spawned by an explosion triggered by a wayward planetesimal could fill the bill. The material ejected into space wouldn't contain much iron because the Earth's mantle didn't, and it wouldn't contain many volatiles because they would have been lost in the explosion. "You would end up creating the moon out of material that would very much match the moon's composition," says Hartmann. The impact could also have been mighty enough to make the Earth spin faster.

They finally published their giant impact model in 1975. Cameron, together with William R. Ward of the California Institute of Technology's Jet Propulsion Laboratory, published the next year. Nothing happened.

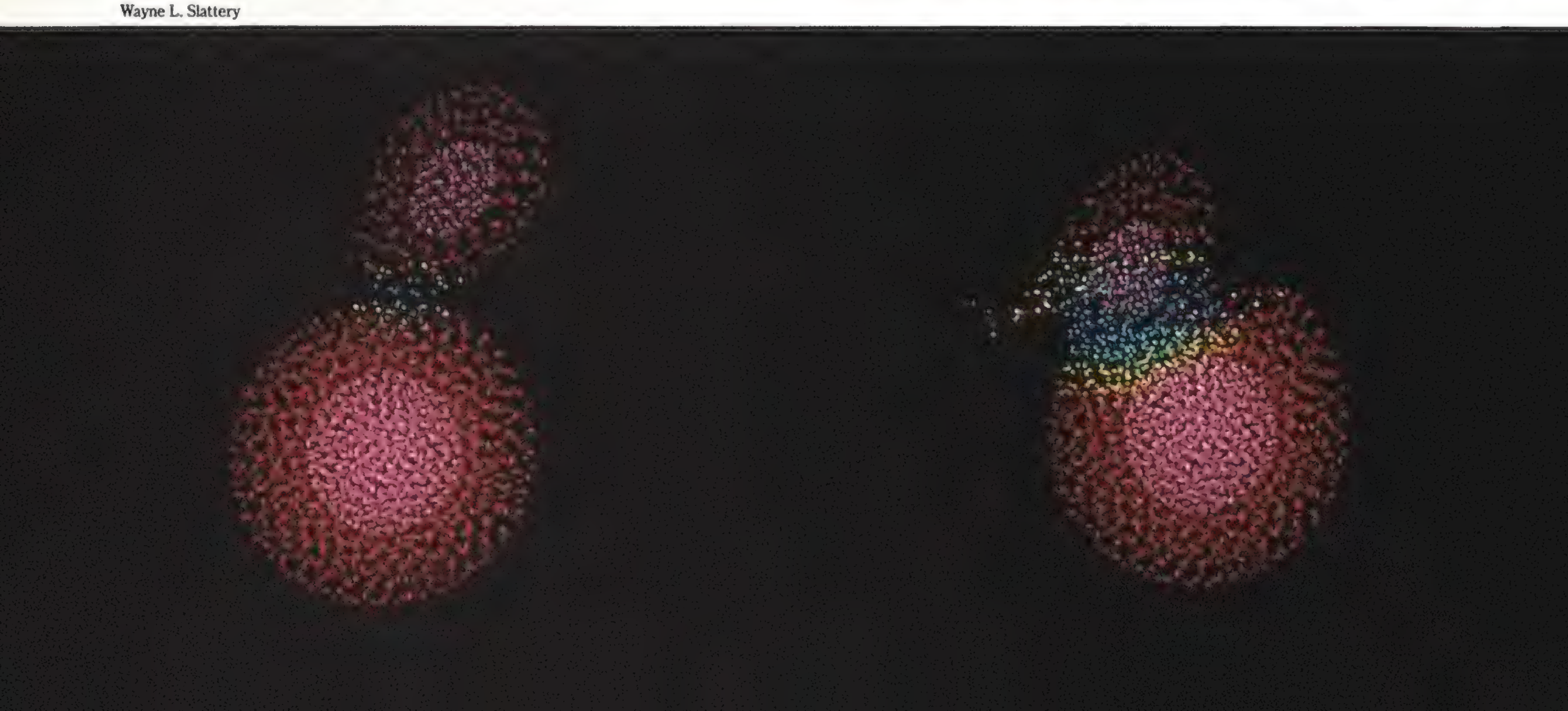
"I went on to some other things," Hartmann recalls. "Both our paper and Cameron's sat around for a few years. Not much more was done." Hartmann says he used to believe that good ideas would rise and be heard on their own. But this time, it didn't work that way. "I probably should have done more to publicize the theory," he says now.

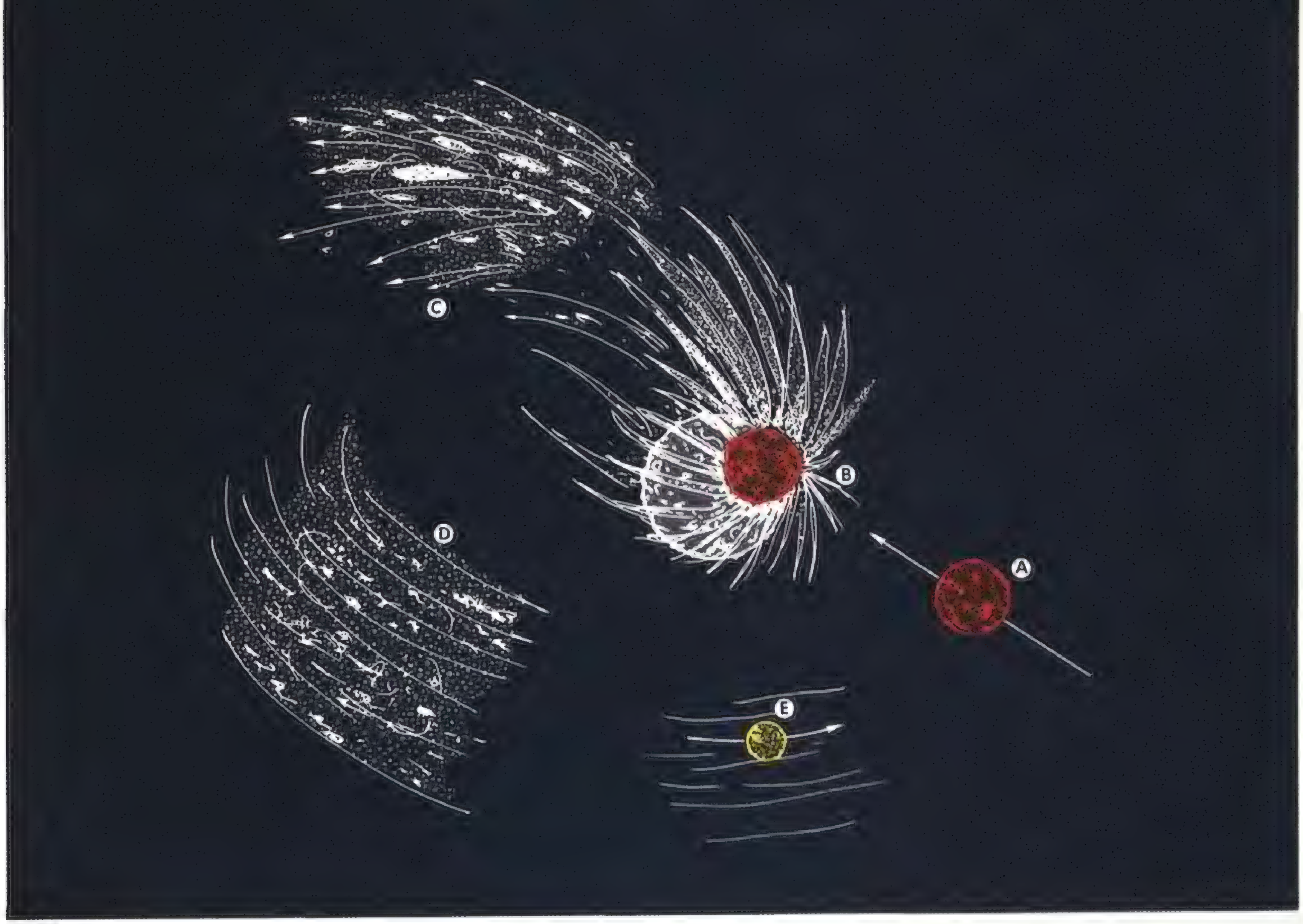
"For almost ten years there was rather little discussion on the origin of the moon," agrees George Wetherill, director of the Carnegie Institution's Department of Terrestrial Magnetism. A nuclear physicist who turned to geochemistry and then to the dynamic problems of the origin of the solar system, Wetherill was at the time studying the general problem of growth of the solar system's inner planets by accumulation and accretion. As for the origin of the moon, "I was working along on it," he says. "I wrote a couple of papers but they really didn't emphasize giant impacts."

Then, in 1984, everything changed. During a brainstorming session a small group of planetary scientists decided that the next workshop in an annual series on the origin and evolution of the lunar crust should be devoted to a grand theme. Hartmann recalls: " 'Why not expand the focus to the origin of the entire moon?' one of the members asked. The idea was instantly appealing."

The time seemed right. The Apollo landings had dealt a severe blow to the three classic theories of lunar origin—fission, capture, and coformation—even if the missions hadn't offered solid alternatives. Some of the theories had long histories. For example, George Darwin, Charles' astronomer son, is credited as author of the notion that the moon had fissioned, or split off, from the early molten Earth as a result of its rapid, unstable spinning. Later, this theory was modified to suggest that a hunk of the Earth was ejected into space, forming what is now the Pacific Ocean in the process. The capture theory is self-descriptive: the moon was captured whole—or perhaps in pieces that later reassembled—when the sphere swooped past the Earth from the outer reaches of the solar system. And in coformation, Earth and the moon formed from the same mix of cosmic debris (although a recent version holds that Earth

Wayne L. Slattery

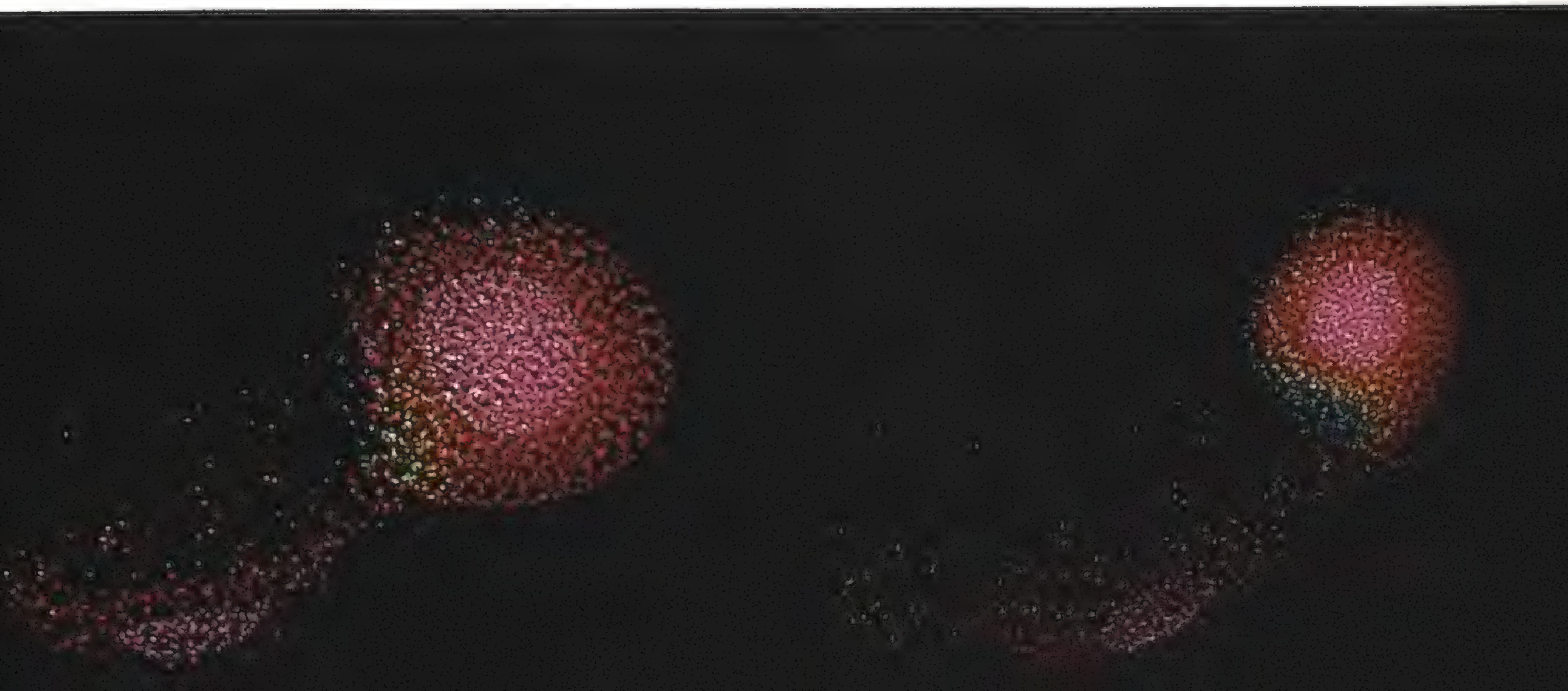




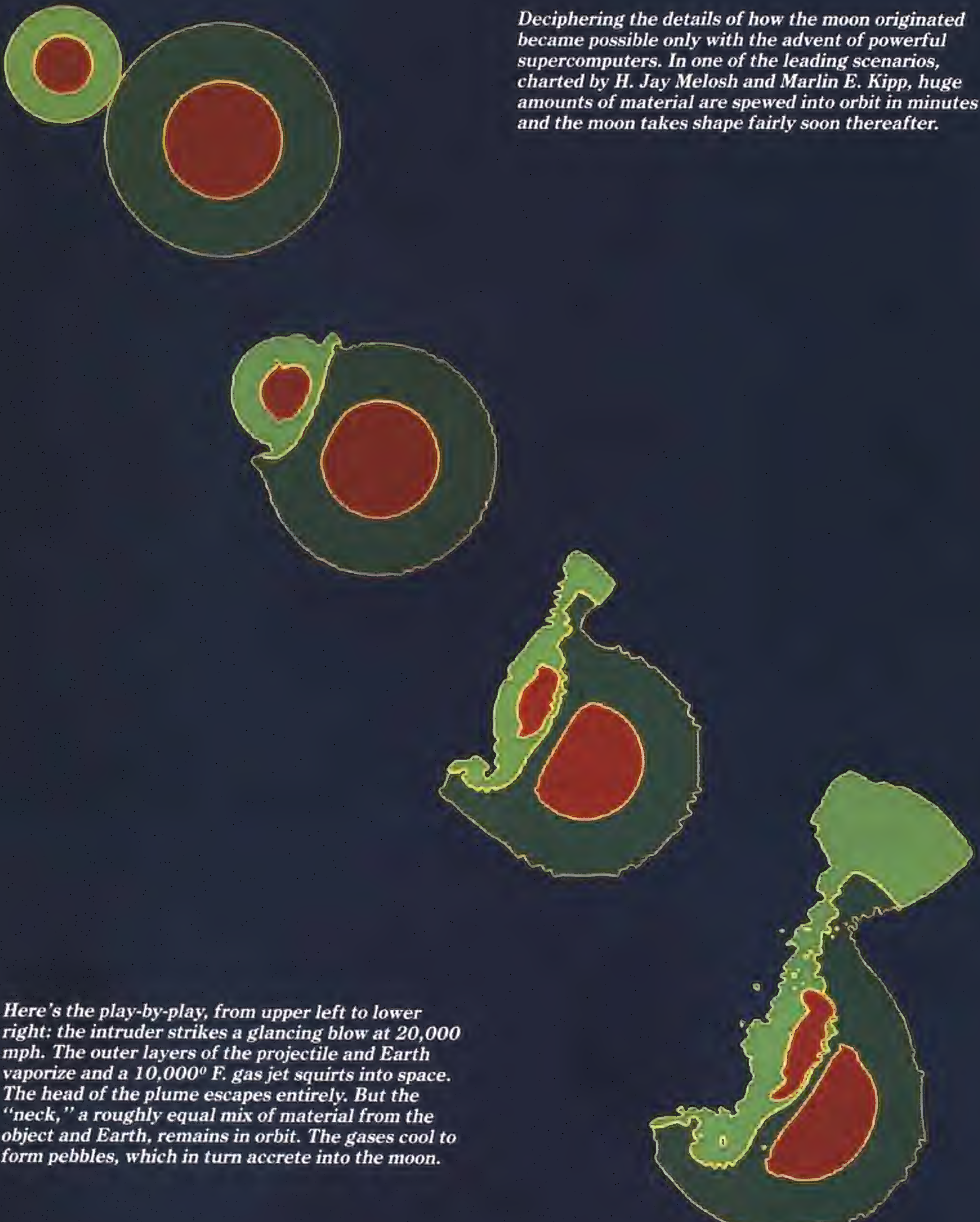
Alan P. Boss

In the giant impact hypothesis, an object the size of Mars (A) obliquely strikes the early Earth (B) and splashes material into space (C). Some of the material achieves orbit, forming a cloud (D) that accretes (E) into the moon.

One version of the birth has been choreographed on a computer by Willy Benz, Wayne Slattery, and theory co-developer A.G.W. Cameron. Here, the object has already hit, been partially destroyed, and spread out in space. Its iron core (purple) drops back to be swallowed by Earth, while rocky outer material remains in orbit to form the moon.



Deciphering the details of how the moon originated became possible only with the advent of powerful supercomputers. In one of the leading scenarios, charted by H. Jay Melosh and Marlin E. Kipp, huge amounts of material are spewed into orbit in minutes and the moon takes shape fairly soon thereafter.



Here's the play-by-play, from upper left to lower right: the intruder strikes a glancing blow at 20,000 mph. The outer layers of the projectile and Earth vaporize and a 10,000° F. gas jet squirts into space. The head of the plume escapes entirely. But the "neck," a roughly equal mix of material from the object and Earth, remains in orbit. The gases cool to form pebbles, which in turn accrete into the moon.

formed first and the moon accumulated from the leftovers).

Hartmann, G. Jeffrey Taylor of the University of New Mexico's Institute of Meteoritics, and Roger Phillips of the Lunar and Planetary Institute in Houston organized the grand lunar event. They mapped out plans for a Conference on the Origin of the Moon, to be held in Kona, Hawaii, in October 1984. It would follow the annual meeting of the American Astronomical Society's Division of Planetary Sciences, which is normally well attended. "It occurred to us," Hartmann recalls, "that by announcing a major conference specifically devoted to the problem of lunar origin, we might encourage new thinking from leading data analysts as well as planetary theorists."

That it did. Many technical meetings turn out to be routine forums, but the Kona conference brought a fresh breeze of scientific thought to the problem of the origin of the moon—along with a sudden burst of research. George Wetherill's response was typical. "One day I suddenly realized I had to give an invited paper at the conference in two months," he says. "It made me address my own thoughts for the first time in quite a while."

"A lot of people buckled down and wrote abstracts of the papers they expected to give," says Hartmann. "Our conveners group met and looked at them. I was surprised and gratified when I saw there was a big bandwagon for a major impact. There had been a lot more computer modeling, and the impact idea had become more plausible and respectable."

Wetherill, for example, reported results of 28 new three-dimensional computer simulations of how planets might take shape from a swarm of planetesimals around the sun. His 42-page paper examined both the accumulation of the inner planets and implications concerning lunar origin. He found that a number of large bodies probably didn't get swept up into planets. Ten of them should have had a mass equal to the planet Mercury and several should have been more massive than Mars. The only way these large bodies could be removed from the swarm was through an impact, normally onto one of the new planets. Wetherill estimated that a third of them would have struck the Earth. He expressed many uncertainties, but concluded on a subtly stated note of support for the new theory: "It is particularly interesting that these large planetesimals provide in a natural way the giant impacts proposed by Hartmann and Davis and Cameron as a way of forming the moon."

Other planetary scientists likewise decided that the moon was formed as the result of a major planetesimal impact. "It's amazing that it happened so quickly, in just a few days at the Kona conference," Alan Boss says with a grin. "It was by far the best conference I've ever been to." Some veteran scientists were there to support the earlier theories, he says, "but you could just sort of watch their enthusiasm fade. It was something to see." Boss' only regret is that the late Harold Urey, the grand old man of lunar science who was responsible for stimulating several generations of planetary scientists, couldn't be there to witness it.

Boss got into the lunar-origin business via theoretical physics, when Stanton Peale, his mentor at the University of California, Santa Barbara, suggested that they work on the origin of the solar system. After joining the Carnegie Institution, Boss eventually entered into a collaboration with Hiroshi Mizuno, a postdoctoral fellow, to study a key problem plaguing the impact hypothesis. If planetesimals in the early days of the solar system could be broken up not just by impacts but also by forces of *near encounters* with the Earth, then there might not be enough large ones left to make a catastrophic collision likely. "We found that it was awfully hard to break them up," he says. "Rocks don't break apart easily." There would be plenty of large objects around so that one could collide with Earth and form the moon.

While the Kona conference was a turning point, two major pieces of work since then have added even more impetus. "I heard about the giant impact hypothesis and was extremely skeptical," says Jay Melosh, a young, bushy-bearded planetary scientist at the University of Arizona who did not attend the Kona conference. "I had done a lot of work on craters blasted out by astronomical objects," he says, adding that the idea of the moon being created as a result of a truly huge impact just didn't ring true. "So I thought I would discredit it. I would work through the calculations and show that it was ridiculous. Well, I worked on it and was instead able to show that it was very plausible. A lot of the details we know about the moon fit the hypothesis without any special pleading."

At a lunar and planetary science conference in Houston, Melosh and colleague Charles P. Sonett submitted a research paper supporting the impact hypothesis. "I thought it'd be an extremely controversial point of view," he says. "There were four other speakers scheduled who I was sure would shoot the whole thing out of the water." Just the opposite happened: "It appears that every one had turned himself around. The entire session was in consensus."

Melosh and Sonett had analyzed the hypothetical impact in detail. They estimated such factors as the approximate speed of the object, what materials would have been ejected from the Earth and the planetesimal, and what path the "ejecta" would have followed into space. They determined that under certain conditions, roughly equal amounts of material from the projectile and the Earth could be lofted high enough to reach orbit. Their paper carried what seemed to them a provocative title: "Worlds in Collision: Jetted Vapor Plumes and the Moon's Origin." The results, they concluded, "are in accord with the mega-impact hypothesis."

While they supported the theory in general, Melosh and Sonett noted some important restrictions. They had determined that it would be essentially impossible for any solid debris from the collision to reach a stable orbit: the principles of ballistics dictate that the material would either keep heading out into space or would fall back to Earth. But their analyses showed a way around the problem—a physical process called jetting. If the collision ejects a plume of vapor rather than solid material, the laws of physics would allow particles from the condensation of the vapor to stay in orbit. In the usual argot of the field, the calculations show that "up to one-half the mass of the projectile may be ejected as an early, high-velocity vapor plume from a moderately oblique collision of two comparably sized spheres," they say.

Their scenario, then, calls for an object about the size of Mars—which has about one tenth the mass of Earth—to strike the Earth at an angle, almost a glancing blow. A plume of extremely hot gas will squirt outward from the intersection

in roughly the same direction that the projectile was traveling. The gas quickly spreads out, and some of the material will remain in orbit.

"Of all the types of ejecta thrown out by an impact," says Melosh, "only the portion that arises from jetting can make a significant contribution to the cloud of debris orbiting about the proto-earth. And that's the stuff that will turn into the moon." Soon thereafter, the vapor condenses into small pebbles. (The Earth also starts to regain its spherical shape and the massive crater starts filling in.) The pebbles grow larger and larger over tens and hundreds of years, and eventually clump together into a solid chunk of material that we would recognize as the moon. Since it will have formed at a distance six times closer than it is today—the moon is steadily receding, thanks to some complicated effects of angular momentum—the object would have been an awesome sight.

To devise even better mathematical models of the moon's birth, Melosh recently joined forces with Marlin E. Kipp, an impact dynamicist at Sandia National Laboratories in New Mexico. Using Sandia's Cray 1 supercomputer, an exceedingly fast and powerful number-cruncher, they have produced new simulations of the early stages of impact. It appears that when the projectile struck, a jet of 10,000° F. gas shot into space. The dense head of the plume kept going, escaping Earth's gravitational hold entirely. But what Melosh and Kipp call the plume's "neck" stayed in orbit, and their simulations suggest that the neck contained enough vaporized crustal material from both the object and Earth to form "at least one lunar mass." Graduate students at the University of Arizona are now working on the theory's geochemical details, Melosh says. "So far, it all looks very good."

Only recently has the moon revealed its most fundamental secret to us, and it's the biggest catastrophe of all.

Another research group that includes A.G.W. Cameron, co-developer of the impact theory, is now performing even more sophisticated computer simulations. A month after the Kona conference, Cameron went to Los Alamos National Laboratory in New Mexico to lecture on his hypothesis. "That's when I met Willy Benz," he recalls. Benz is a Swiss astrophysicist doing postdoctoral work at the laboratory with a former student of Cameron's named Wayne Slattery. Benz and Slattery told Cameron they wanted to test the giant impact theory using complex software programs that Benz had helped develop for astrophysical studies. A collaboration was quickly arranged. Cameron's own calculations had established that the impact of a single planetesimal could have packed enough of a wallop to have given rise to the moon, but they were too crude to allow any quantitative predictions.

In their initial simulations, using the laboratory's newest Cray XMP supercomputer, they assumed for simplicity that both the Earth and the planetesimal were made entirely of granite, with no metallic core. The impact resulted in the formation of various clumps of material in a low, unstable orbit. Gravitational forces then broke apart the clumps, and a disk of material spread around the Earth. Part of the material managed to creep out into a more distant orbit and form the moon. If you crank in the proper physical requirements, says Benz, "the formation of a moon is almost straightforward." Benz produced the first color movies of this simulated event. But the work hasn't stopped there.

"What has happened since is both dramatic and important," says Cameron. Benz modified the software so that it could incorporate iron cores in both bodies, a more realistic scenario. "How do you get rid of the iron core of an impactor?" Benz asks, since we know that the moon is relatively poor in iron. "That was a major concern with the giant impact theory." The group ran the first of the new simulations early in 1986. "You get something very nice," says Benz. "We found a little different behavior."

To their surprise, the simulations showed two separate clumps ending up in temporary orbit about Earth. One is the planetesimal's iron core, the other its granite mantle. No material from Earth finds its way into space. The intruder's core, being heavier, spirals back to Earth and sinks into its iron core. "After one rotation it just gets swallowed by the Earth," he says. But before that happens, it has an important effect. For a brief period the Earth, the iron core, and the mantle clump constitute what's called a "three-body system." The complex interactions among the three bodies perturb the orbit of the mantle clump, giving it a gravitational nudge outward. "It's sort of a pull to the side," Cameron says.

The mantle clump remains in orbit, but in an orbit different from their first scenario—high enough to be stable. "So you end up forming a real moon and not just a disk that then has to go through accretion," Benz says. "The dramatic thing," adds Cameron, "is you get a body formed with a mass close to that of the moon—embarrassingly close, as a matter of fact. These new results change many of the basic features of the impact hypothesis in a very fundamental way."

The new Benz-Cameron studies differ from the Melosh-Kipp studies in several ways. For example, they don't invoke a vapor jet—instead, the three-body nudge puts the proto-moon material into stable orbit. And they seem to indicate that the moon was formed primarily of material from the incoming object's mantle—it was not half-Earth, half-intruder.

The two groups have barely had time to compare results, let alone make them available to the larger scientific community for evaluation. But, says Alan Boss of the Carnegie Institution, what's most important is that both studies strongly support the plausibility of the giant impact hypothesis.

However, not all planetary scientists have climbed on this bandwagon. It is premature to rule out several of the earlier theories, some say, and there remains a chance one will be modified and combined with the giant impact hypothesis. One holdout is Richard H. Durisen, an astronomer at Indiana University. He has joined with Australian scientist Rober Gingold to present new numerical simulations to test the fission hypothesis. Their results suggest that the original idea, that the moon split off the early Earth as a discrete solid object, can't

William Hartmann

New lunar missions, including a hoped-for orbiter to gather geological data, would help fill gaps in the impact theory.

be correct. But instabilities generated by Earth's rapid spinning could have caused a ring or disk of debris to be ejected into space, which then accreted to form the moon.

This revised view avoids some technical problems associated with fission. But Durisen himself notes serious objections: "It is difficult to make the proto-earth rotate fast enough to undergo fission, and it must be largely molten at the time it fissions." He suggests combining his hypothesis with the giant impact scenario. "One or several grazing collisions by Mars-sized or larger bodies may be necessary to trigger fission," Durisen says. "In this case, fission loses its standing as an independent theory but remains a process which must be further considered. I think it is important to offer some resistance to the impact hypothesis bandwagon, just to keep researchers open-minded."

G. Jeffrey Taylor of the University of New Mexico, one of the organizers of the pivotal Kona conference, also argues for open-mindedness. "The other ideas have not really been so completely thrown out as many scientists might suspect," he says. For example, it's possible that a planetesimal might have sufficiently speeded up Earth's rotation to cause the kind of fission that Durisen suggests. No process should be considered *the* theory for the origin of the moon, Taylor maintains, but as something that perhaps happened during its formation. "I like the idea of an amalgamation of processes," he says, "where a big impact plays a big role."

Still, the work of the teams led by Melosh and Cameron is now at center stage. Both sets of simulations came about largely thanks to the advent of supercomputers with enough speed and memory to carry out millions of calculations. This, says Cameron, means the advances really couldn't have been made much earlier than they were. If the new view of lunar origin is correct, the moon was born in violence in a very few minutes back near the dawn of the solar system, but complete awareness of this event had to await the computer technology of the late twentieth century.

How does Cameron feel now that the giant impact hypothesis he helped advance more than a decade ago has finally become the lead contender among moon-origin theories? "It's always nice to back the right horse for once."

Photographs courtesy George Long

Christmas in the Azores

In the first winter of transatlantic air service, passengers sometimes didn't know when they would get home—or where they would spend Christmas.

By George Long

Compared to news reports from the four-month-old war in Europe, the item in the *New York Times* on Christmas Eve in 1939 was of minor importance. "Pan American Airways," it reported, "last week marked up the 100th regularly scheduled crossing of the North Atlantic by its forty-one-and-one-half-ton Boeing Clippers." Little could Pan Am know that the most implacable enemy ever—the weather—had already begun a complete disruption of its transatlantic service, forcing some passengers to spend the entire holiday season on a small island in the middle of the ocean.

Pan Am had unveiled its transatlantic service in May, only 12 years after Charles Lindbergh made his famous solo crossing. The only long-range passenger aircraft then suitable for transatlantic flights were flying boats, great spacious hulls with wings and engines. Not only could they fly long distances, they also didn't need much in the way of developed landing areas—adequate rivers, lakes, bays, and the like were available almost everywhere.

The most direct route between the East Coast and Europe—with stops in New Brunswick, Newfoundland, and Ireland—was limited to the mild summer months. The only satisfactory year-round route looped farther south, with a stop in the Portuguese-owned islands of the Azores. But while the weather was better, this route had one drawback: the best harbor in the Azores, Horta, located on an island called Fayal, wasn't large enough for landings and takeoffs. The big flying boats had to come and go from the open ocean and taxi in and out of the snug harbor.

Flying boats arriving to refuel in the port of Horta sometimes had their wings temporarily clipped by high seas.

Open-ocean landings were usually no problem. The flying boats could easily handle the ordinary waves kicked up by local winds. But undulating ocean swells, which are generated by massive weather systems and can travel thousands of miles, were another matter. The tons of water in each swell could become too much for the hulls of the flying boats to handle during their takeoffs. Practical experience had shown that the maximum swell height for a safe takeoff was two and a half feet. This limitation was not a serious problem during most of the year, for the sea around the Azores was usually calm—usually, but certainly not always.

On December 23, two westbound Boeing B-314 flying boats, the *Atlantic Clipper* and the *Dixie Clipper*, had arrived in Horta from Lisbon, Portugal, en route to Pan Am's seaport facility at Port Washington, Long Island. Their 34 passengers were a mixed group: businessmen; tourists; government officials; a Polish war hero, General Josef Haller; and Chaim Weizmann, head of the Jewish Agency for Palestine, and later Israel's first president. All were eager to reach the United States, but even as the flying boats touched down the swells measured three feet. The rough landings left no doubt there would be an overnight stay at the airline's hotel in Horta, with the hope of better weather the next day.

But better weather would be a while in coming, said the meteorologists. And indeed, the next morning airline personnel didn't even need to make the usual observations by boat to see that the swells were up to five or six feet. While distressing to the passengers, the delay became a blessing for the local telegraph business, which cabled the detainees' Christmas messages to people throughout the Western Hemisphere.

When Pan Am's flying boats first used Horta, many women still wore capots, a style from the eighteenth century (above).

After censorship fears were laid to rest, the detainees' newspaper resumed publication with its fourth issue (right).

Stranded for who knew how long, some passengers tried to make the unscheduled stay productive. Gerald Deakin, a vice president of ITT, was able to inspect the company's subsidiary, Commercial Cable. (Centrally located among four continents, Horta had become the major meeting point for underwater telegraph cables.) Commercial's manager, John O'Shea, was a hospitable Irishman, and with his wife Edith made his boss welcome. The O'Sheas also had four daughters, who gradually became centers of the holiday social season.

Other passengers became caught up in the spirit of Christmas. Benito Bourde, a Mexican businessman, had the O'Shea offspring help him gather the best of the limited toys and dolls in the city's shops and deliver them to the 42 children—all girls—in the local orphanage. When Bourde saw their meager living conditions, he decided to buy them new coats as well. Not surprisingly, the stores couldn't provide 42 coats, so Bourde arranged for the material to be brought in later from Lisbon, and the girls (who had been taught sewing at the orphanage) were able to make their own.

And what would a stay on an ocean isle be without romance? One of the detainees, a vivacious Irish lass named Juliet Kelly, was soon courted by a pair of ardent and competitive fellow passengers. When one would-be beau protested that the other's ample wardrobe gave him an unfair advantage, his rival agreed to a deal. After a visit to a local tailor, the suitors soon resumed their attentions to "La Kelly," wearing identical checked suits, shirts, ties, and hats.

In the meantime, another member of Pan Am's flying boat fleet, the *American Clipper*, was also stranded in mid-ocean. This airplane had been sitting idly in Bermuda, also a stopping place on the southern air route, waiting for improved conditions so it could finish its eastbound flight to Europe. And on the 29th, the *Yankee Clipper* joined its sister ship in Bermuda with a cargo of mail and passengers.

Back in the Azores, the island of Fayal had begun working its charm. Only about 30 miles around, this extinct volcano was covered with lush vegetation, and even in December flowers were plentiful. Particularly beautiful were the blue hydrangeas—Fayal is known as the "Blue Island"—in enormous bushes along the narrow roads. The people of Horta welcomed the stranded travelers into their homes, sympathetic to their melancholy at being away from home during Christmas, and excited at the prospect of having so many unexpected visitors during the holiday season.

Nor did the passengers lack for entertainment, for along with its palm trees and fishing boats Horta also offered nightlife. Local merchants maintained a club that had all the comforts of home. There was a restaurant that offered steaks and local seafood, and its elegant ballroom featured an orchestra that played the latest Glenn Miller arrangements as well as the

THE HORTA SWELL

NUMERO 4 HORTA, FAYAL, AÇORES 3 JANEIRO 1940

RE-ENTER THE SWELLS

Sincere apologies, dear public, for our brief absence. We missed you and fully appreciate the numerous demands for our reappearance, in fact, as you see we have been unable to withstand them. Here we are again complete with all our most popular sections.

It is just possible that somebody might not have heard *why* we did not appear yesterday. We were advised from certain quarters that we should quit. We spent all yesterday trying to guess the causes of this displeasure, and though we were not so successful as in tracking down the Bathroom Vampire (see Crime Section), we think we have eliminated whatever it was by changing everything important. For instance, we printed the paper upside down, so that top is where bottom was. Radical red has given place to swell green, and every article in this issue is brand new.

Is it all right now?

THE SWELL AND THE UNDERTOW

January 2, 1940

To the Editores, The Horta Swell
Senhores :

What-a-for you makka the wail because why you stay at Horta? You no likka nossa ilha? You no taste the nature's beauties? You no smell the camellias? You no see the ocean majestoso? You no hear the musica from the wind? You no drinka the *secco 1906* for a trifle escudos? You no enjoy our Club Amor de Patria? Why you no thank the SWELL he go up and down ! You have unico privilégio ! Why you no settle down, you no borrow the money, you no makka friends, you no relax?

X. Y. Z.

January 2, 1940

To the Horta Swell-head
Sir (or ever worse, madam ?):

Whatever your arrogance, you cannot deny to a victim of your socalled humour the right to point out that your feeble efforts to be witty are serving no useful purpose. There is plenty of room on this Crusoe's island for a serious publication that would express the emotions that choke us when our thoughtsrevert to our common desolation.

And what do you do instead? You smirk, you flatter, you strip-tease, you take-off and taxi back, you bury your insults in mealy apology, you clench your fists only to pull your punches! In short, in the opinion of many, you are a trimmer of a most suspicious sort. Who are your real backers anyway? What secret interests are you serving? Who pays for your wine? Come out of your musty cellar and let us identify you.

A disgusted passenger

SWELLING HOPE

«On the road to Mandalay
Where the flying fishes play...»

Ship me somewhere West of Horta
Where the swell can never rise,
Where there ain't no weather forecasts,
Or strange things that haunt the skies.
For Fifth Avenue is calling,
And it's there that I would be...
After voyaging the «Rex» way,
Really crossing swelling seas.
Really crossing swelling seas .....
On the road to New York Bay,
Where the Italian Line Piers lay—
Can't you hear the Late News Extra
All about our sad delay?
On the road to New York Bay,
Where the Italian Line Piers lay—
All our hopes swell up like thunder,
Cause the «Rex» is on the way !

REX LINE

Coat hangers is every closet
Mirrors in every room
Regular schecule

COMPOUND COMMENTS

by

Camille d'as Camellias

The New Year's Party was a *success*...

Mr. Maxwell Munce surpassed himself as the Compound Caruso... and Mr. Robinson was *eloquent* on the triangle.

Colonel Pope to Mr. Flanley—I object to promiscuous osculations !

Mowrer's hair was too *magnificently* flamboyant ! (see cut).

We *missed* Sir Vivian—was he up on Pico looking for the Fleet?

We were so glad that Mr. Barry was frantically, madly, awfully... *gay*.

By unanimous vote the Graham Towers remain our most elegant.

The *sheer* excitement of Léona Bucklin doing the «Cucaracha».

Vizconde Domecq looks *toooo* aristocratic under a barrel.

Time practically stood still while tall dark and handsome Paine.. marched on !

We *regret* that Emir Thornburg's oriental regalia consists of a Dunhill briar pipe.

Overheard—I *can't* go through life with *six dots* after my name !

We hear that Mr. Warren *eclipsed* Arthur Murray—enrol now for this special New Year's Eve fandango classes.

La Kelly was positively. . *thrilling* !

THE RAPE OF THE LIPSTICK

OR

THE BATHROOM VAMPIRE

The Vampire committed one fatal mistake, he left fingerprints which our detectives tock down shorthand in the approved manner. Using our only means of communication, these were promptly submarine cabled to the C. I. D. in Washington, and we now have full information. But...the criminal is still at large, the danger to toilette articles and ephemeral lingerie is still alive. It is well known that a murderer always strikes twice. Until we can assure our public that there is no further danger we must be silent. The dragnet is closing down.

Any moment now!

Watch for further developments in our next issue.

Tip. de O TELEGRAFO—Horta

newest tunes from the Continent. Called *Amor de Patria,* or Love of Country, the club opened its doors to the newcomers and helped make the holiday season merry.

Some of the passengers passed the time by putting out a daily newspaper. It seemed a logical thing to do, as *Chicago Daily News* foreign correspondent Edgar Ansel Mowrer was among them. With a local tavern as headquarters, candles for illumination, and Pico Red wine for inspiration, they set to work. The budding publishing tycoons called their paper the *Horta Swell,* and on the front page surrounded the name with palm trees, two islands, and rolling waves. The first issue, dated December 30, consisted of an announcement of the new publication (which grimly conceded that they might as well settle in for the winter), a parody of "The Night Before Christmas," and a number of gossip items about individual passengers. There was also a thank you to the people of Horta, and especially to the *Amor de Patria,* written in a farewell tone that suggested premature optimism.

Jibes at Pan Am—"It Tries to Fly" was one of the milder barbs—regularly saw print. Most were offered in reasonably good spirit, but the airline's local manager wasn't amused. He reminded the writers that the Azores were governed by Portugal, a dictatorship that had censorship laws covering newspapers. Unfamiliar with the local atmosphere and unwilling to create a problem with a foreign government, the entrepreneurs decided to give up their enterprise. But when the writers mentioned this to Commercial Cable's O'Shea, he arranged a meeting with the local captain of the port, who also served as censor. The captain assured them that their publication was not considered a threat to the state and, in fact, he enjoyed it. The *Horta Swell* resumed publication.

The ocean swells were now calming a little, but had yet to reach a safe level. Each day Pan Am's survey boat spent hours at sea, looking for protected inlets or other areas with enough smooth water to permit takeoffs. But even if the flying boats could take off, upper altitude head winds were growing stronger and would have forced some passengers to be left behind to compensate for increased fuel needs. An ever-optimistic Pan Am would periodically board a carefully calculated load of passengers and fuel, then release the airplane to taxi out in a vain effort to find a takeoff area outside the harbor. These maneuvers became known as "suitcase drills," and some cynical passengers requested that they be held at times that would not interfere with meals, while others suggested that picnic lunches should be taken along. Those who had to remain behind would greet the disappointed passengers with good-natured teasing upon their inevitable return to the dock.

More days passed. With the swells showing no signs of diminishing and all four of Pan Am's Boeing clippers stranded in the Atlantic, airline officials were faced with the ultimate indignity—they had to find alternate transportation. The company arranged for the Italian ocean liner *Rex* to make an unscheduled stop at Horta on its next regular trip from Italy to New York.

In a cruel twist of fate, the swells began to diminish almost as soon as Pan Am summoned the *Rex.* On January 3, after the flying boats had been at Horta for 11 days, the swells were low enough to permit takeoffs, although the head winds aloft limited their payloads. When the airplanes left, only five passengers went along for the bumpy, 21-hour trip to Bermuda and on to Pan Am's winter seaport facility in Baltimore.

The crews of the two flying boats stranded in Bermuda also took advantage of the improved seas. The *American Clipper* completed its journey to Lisbon. But Pan Am dispatched the *Yankee Clipper* to Horta to pick up the remaining passengers and complete their delayed flight.

It was not to be: the swells returned in strength and now stranded the *Yankee Clipper.* Life continued on hold, but enthusiasm was dwindling. January 7 saw publication of the final issue of the *Horta Swell.* Along with the usual gossip and a crossword puzzle, it contained a farewell, in Portuguese, from the young people of Horta to their new friends: "Destiny has its whims, and therefore the unhappiness of some becomes the delight of others. As prisoners of the island of Fayal due to the weather, it was your misfortune that gladdened our small city and, above all, our festivities."

The *Rex* reached Horta on January 11, but the ocean managed to take one last swipe at its victims. Just hours before the ship arrived, the swells rose to a distressing height. Since the harbor couldn't accommodate the huge *Rex,* the passengers had to be ferried out by launch. However, the swells rendered use of the gangway impossible, and the boarders had to suffer the indignity of being pushed from below and pulled from above through a door in the ship's side—all coordinated with the rising and falling of the seas.

Four passengers had elected to remain behind and wait for conditions that would allow takeoff. January 14 proved to be the lucky day. The *American Clipper* arrived in Horta on its way back from Lisbon and loaded up the holdouts and a record 7,654 pounds of delayed mail. Accompanied by the *Yankee Clipper,* the great flying boat lifted off and headed west.

So ended one of the longer flight delays ever. The last of the passengers arrived in Baltimore the next day, more than three weeks after they had left Europe. "With all the submarines and mines it is safer to go by air," Rene Brisac, a representative from a Paris perfume company, told a *Baltimore Sun* reporter, "even though it may be slower."

By Junius Ellis

Entrepreneurs In Space

Can three Harvard MBAs and a Texas wildcatter take on the aerospace establishment? Tune in for the Adventures of Orbital Sciences.

Last summer's rollout of a squat, 11-foot-long rocket at Martin Marietta Corporation's Denver Aerospace subsidiary drew little public fanfare. But the significance of the event wasn't lost on the crowd of industry and government representatives who came to inspect the new Transfer Orbit Stage (TOS) booster developed by Orbital Sciences Corporation and commend the customer who bought it. The National Aeronautics and Space Administration had finally decided to purchase the $30 million rocket for a Mars Observer scientific probe scheduled for 1990. What made the deal out of the ordinary was that Orbital Sciences, not NASA, picked up the bill for the TOS's $60 million development cost.

Not bad for a venture borne of a graduate-school project, nurtured by moonlighting, and sustained with youthful chutzpah. Orbital Sciences' founders—Bruce Ferguson, 31, David Thompson, 32, and Scott Webster, 34—who started the company in 1982, soon after graduating from Harvard Business School, are ecstatic over landing the NASA contract and unfailingly optimistic about future business prospects. Along the way to their first sale, the trio had to cajole NASA into sanctioning the project, hire Martin Marietta to build the solid-fuel booster, and scramble to raise start-up money.

But enthusiasm—even combined with one factory rollout—doesn't guarantee long-term success, and the founders face some tough times ahead trying to market their brain child. That's because the TOS is an "upper stage" booster to be used primarily in tandem with NASA's space shuttle. The shuttle would deliver a satellite or spacecraft to low-Earth orbit with a TOS attached, and the booster would then kick the object into a higher orbit or toward some far-flung celestial body.

The TOS is not just a new machine. The three biz-kids, convinced by President Reagan's endorsement of private investment in launching commercial satellites, believed they could "participate in a revolution in how American industry approaches business opportunities in space," as Thompson puts it. The aerospace industry traditionally develops projects with NASA or Department of Defense funding, and when the government decides to move into construction, the original contractor usually gets the job. Competition is effectively ruled out, and companies rarely risk their own capital to gain a foothold in someone else's market, however lucrative it may become.

Orbital Sciences, located in a Virginia suburb of Washington, D.C., set out to beat this system by convincing NASA that it was willing and able to undertake the TOS project on speculation. "We saw a great opportunity to gain admission to an exclusive club normally closed to entrepreneurs," says Thompson, company president and the only partner with previous membership in the aerospace fraternity. "And we got into the business before anybody realized what was happening."

Thompson is a self-proclaimed space cadet who's determined to be on the shuttle for the first TOS launch. His zeal, shared by partners Ferguson and Webster, dates back to his boyhood: enshrined in his office is a photograph of a crude, seven-foot rocket that he built as a teen-ager in Spartanburg, South Carolina. The reusable rocket, which carried small monkey astronauts to an altitude of 2,000 feet and dropped them gently to the ground by parachute, performed flawlessly on three of its four launches. "I'm sorry to say that one of the monkeys gave his all for the cause," Thompson laments.

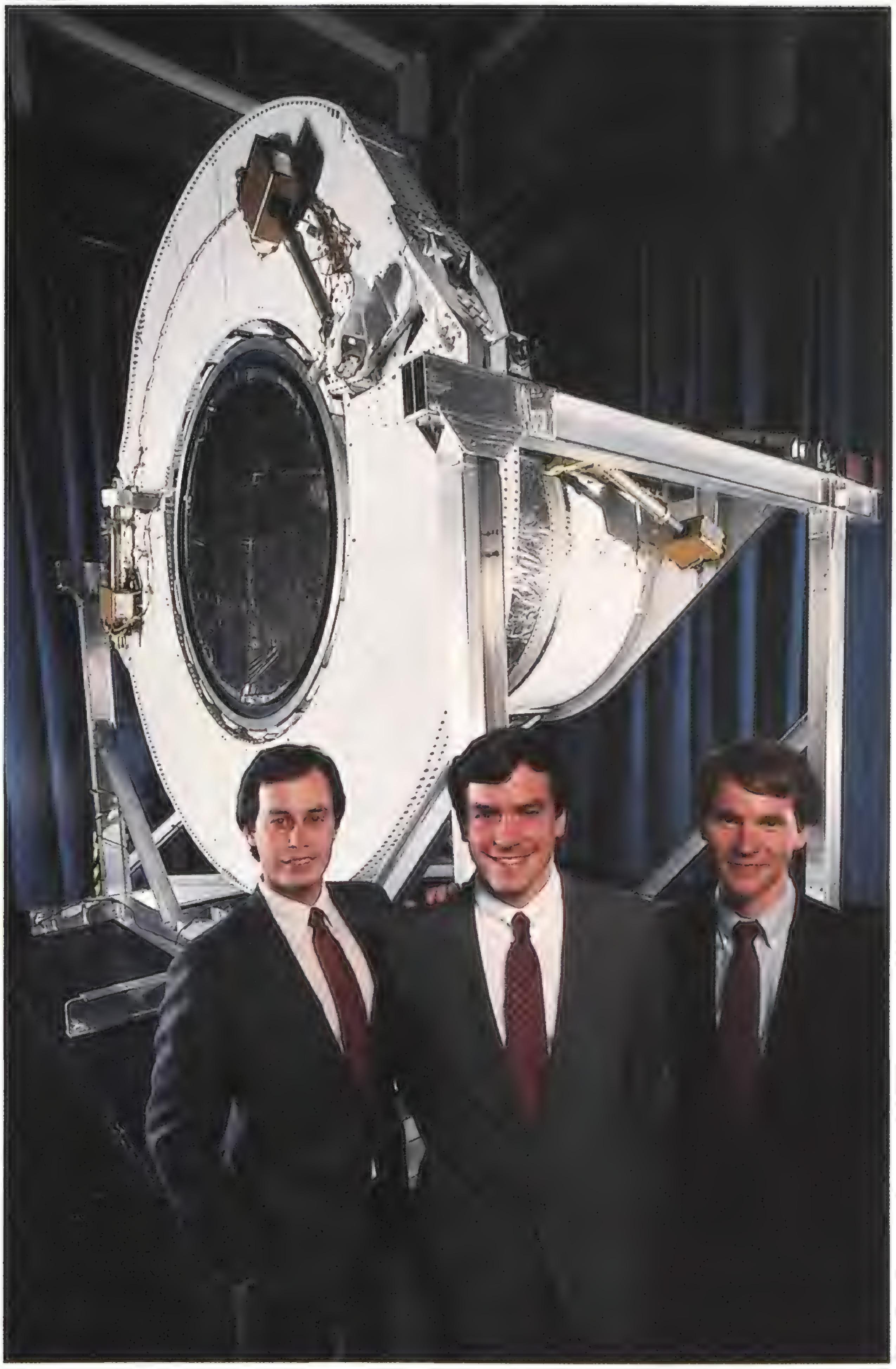
The accomplishments of this budding Wernher von Braun impressed admissions officers at the Massachusetts Institute of Technology, which awarded Thompson a scholarship named in honor of U.S. rocket pioneer Robert Goddard. After graduating first in his class in aeronautics and astronautics, he went on to earn an advanced degree at the California Institute of Technology and a job at NASA as an engineer on the shuttle program. But space ennui soon set in. "I felt stifled by the agency's go-slow attitude," he recalls. "So I decided to make things happen myself."

Thompson enrolled at Harvard in 1979, where he met Webster, a mechanical engineer from Eveleth, Minnesota, and Ferguson, a Washington, D.C., native pursuing a joint degree in law and business. The friendship deepened as they took part with several other students in a NASA-sponsored class project studying commercial opportunities in space. Of particular interest was the potential of the shuttle, then being readied for its inaugural flight in 1981, as a facility for materials processing.

After completing the study, the threesome turned their interest to what they considered a better near-term opportunity—a space transportation system built around the shuttle. This was the picture: the reusable shuttle would be cheaper than expendable rockets such as the Atlas, Delta, or Titan for launching commercial and government satellites, but it was an open question as to whose upper stage booster would be used to kick the satellites into a stable "geostationary" orbit 22,000 miles above the Earth. The proverbial light bulb clicked on.

"Upper stages seemed ideally suited

David Hiser



All they need is a ride for their booster rocket and then Scott Webster, Bruce Ferguson, and David Thompson (left to right) can join the aerospace big time.

to private investment because of their fairly simple technology, modest development cost, and large customer base," Ferguson recalls. "Yet only McDonnell Douglas had taken the initiative to fund its own shuttle upper stage." The company's Payload Assist Module (PAM) could deliver about 2,000 pounds to geostationary orbit, which meant it could accommodate most of the day's communications and surveillance satellites. But on the drawing boards were increasingly bigger satellites designed to exploit the dramatic savings made possible by the heavy-lift shuttle.

For boosting very large payloads weighing up to 10,000 pounds into geostationary orbit, NASA and the Department of Defense had contracted with Boeing Aerospace to develop an Inertial Upper Stage booster and with General Dynamics to develop a shuttle-compatible version of the Centaur booster. But the three fledgling astropreneurs saw an opening in the market for a mid-sized, all-purpose booster that would be priced right for commercial customers and suited to government missions, too.

Upon graduating in June 1981, the trio came down to Earth for a while and landed jobs that took Ferguson to the law firm of Kirkland & Ellis in Chicago, Thompson to Hughes Aircraft's Missile Systems Group in Los Angeles, and Webster to Advanced Technology Laboratories in Seattle. They continued to exchange ideas gleaned from their grad-school project, but their insights might well have remained academic were it not for a $5,000 award bestowed on the group by the Space Foundation, a non-profit organization of Houston business executives devoted to promoting private enterprise in space.

The prize barely covered the team's travel expenses to Houston for the award ceremony. But it strengthened the resolve of the three aspiring space businessmen to begin their booster moonlighting efforts in earnest. Before heading home, they divied up responsibilities: Ferguson would handle the finance, Thompson the engineering, and Webster the marketing. Events then began moving swiftly.

They delivered their first appeal for money to Sam Dunnam, then the Space Foundation's president. "We had drained our bank accounts and charged our credit cards to the limit," Webster says, "and we still had a lot of work ahead of us." Dunnam referred the threesome to his friend and fellow foundation member Fred Alcorn, a Houston oil and gas wildcatter with a penchant for high-risk ventures and deep pockets to feed the penchant. "I may have been a bit naive," Alcorn reminisces. "But the young men's ideas made so much sense that I knew right away I wanted a piece of the action. I told them to draft

an offer and bring it back after lunch."

Huddled in a nearby deli, they sketched out a financial proposal on a napkin, and then returned to Alcorn's office to type a finished copy. They left with an agreement that Alcorn would become the company's fourth partner for $30,000 plus a pledge for more money once NASA gave its go-ahead with a signed endorsement.

Flying high, the trio returned to their respective jobs, grabbing time whenever possible to prepare their pitch to NASA. In October 1982, Thompson and Webster attended an aerospace conference in Washington, D.C., where they heard Jack Wild, then head of NASA's upper stage program, outline the need for a new type of mid-sized, shuttle-compatible booster. He coined the name transfer orbit stage, and argued that this booster could be developed for all kinds of customers at a reasonable cost using components already on the shelf at NASA and the Department of Defense. What's more, Wild said NASA had long-range plans for up to ten missions that would need a TOS.

The leaders of Orbital Sciences perceived Wild's proposal as removing one of the biggest bureaucratic obstacles in their path to NASA's blessing: the not-invented-here syndrome ("it's not our idea, so it can't be any good"). Their task now was to convince NASA that three MBAs and a Texas wildcatter represented a viable alternative to established aerospace companies and government-financed projects. Thompson and his partners finally pulled off a meeting with Wild and his staff in December. "I figured I'd give these kids a quick hearing and then throw them out," Wild recollects. "Well, Thompson really did a sales job—turned us completely around. We agreed to give them a chance to show us they were for real."

The chance was six weeks to prove that Orbital Sciences could handle the project technically, fund it, and manage it. The founders promptly quit their jobs and set up an office in Thompson's Los Angeles home. Fred Alcorn upped his ante to $250,000 and secured a $2 million line of credit with his bank. With a week to spare, the company lined up Martin Marietta as its contractor and hammered out a management plan that included several former NASA and industry engineers in key positions.

In return, NASA committed itself to little more than providing technical advice and monitoring Orbital Sciences' progress. The agency did promise not to develop a competing TOS-type booster on its own, but it would not promise to buy any of the company's boosters. In fact, NASA announced that it would consider proposals for privately financed upper stage projects from any aerospace company that might be interested. There were a few tentative queries but, luckily for the fledgling venture, no serious proposals.

Orbital Sciences' founders dream about holding a board meeting in space by the end of the century.

Still, NASA officials continued to postpone signing the formal agreement that Orbital Sciences needed to attract more investors. But any hesitancy that the agency may have had about the pending deal was probably dispelled on April 5, 1983, when the first of Boeing's Inertial Upper Stage boosters misfired while trying to launch a top-priority Tracking and Data Relay Satellite from the shuttle. Two weeks later NASA and Orbital Sciences came to terms and signed a formal booster development agreement.

This step prompted a feature in the *New York Times*. The article caught the eye of Nathaniel Rothschild, a member of Europe's famous banking family, who was fuming over the nationalization of several Rothschild businesses by France's new socialist leaders. "I think Rothschild saw us not only as a smart investment but also as a way to even the score with the French government," explains Thompson. "If TOS helped attract more customers to the shuttle, so much the worse for France's Ariane rocket." In June, an investor group led by Rothschild provided Orbital Sciences with a critical $1.8 million infusion for the cash-anemic company.

It was a heady time for the young entrepreneurs, who worked and traveled around the clock, drafting proposals, making presentations, and scrutinizing production schedules. By 1984, the partners had raised $50 million for research and development through a limited partnership, the largest amount ever in the aerospace industry. But every now and then they would pause to muse over their rocket-driven dreams, among them the goal of holding a board meeting in space before the end of the century—a fitting rite of passage for their middle age.

They may daydream a lot about this these days, perhaps seeking relief from trying to poke through the clouds obscuring their future in space. Shuttle flights are on hold until at least 1988, and without the shuttle, TOS may have a hard time finding a ride into orbit. What's more, the week before the TOS rollout in Denver, President Reagan announced that NASA should no longer launch commercial communications satellites on the shuttle.

That declaration was anything but a blessing on Orbital Sciences' coming-of-age ceremony. The company estimates that communication satellites would have accounted for nearly half of the shuttle-TOS bookings anticipated through 1992. Moreover, it's not clear whether any of these prospective customers may switch to Martin Marietta's premium-priced Titan launcher, the only expendable vehicle with which the TOS is compatible. Notes Christopher Demisch, an aerospace analyst with First Boston Corporation, an investment banking company: "Most customers bumped from the shuttle are sure to get a more attractive, government-subsidized launch price from Arianespace," the French-led business that operates the Ariane launch vehicle developed by the European Space Agency.

Once the shuttle resumes operation, Orbital Sciences' business may pick up. NASA already holds an option to buy boosters for three more spacecraft and may order another to launch its Advanced Communications Technology

Orbital Sciences Corporation

The first mission for Orbital Sciences' booster will be to hurl a scientific spacecraft to Mars early in the next decade.

Satellite. The company is also trying to sell NASA on the TOS for a dozen potential missions, but most of these projects are not yet in the agency's budget and may never be more than wishes on paper. Moreover, any of the proposed missions could be designed for launching on vehicles other than the shuttle or the Titan, putting Orbital Sciences' booster out of the running.

But while the company waits for NASA's plans to jell, it is planning to go after a contract with the Air Force for up to ten boosters for military payloads to be launched by the shuttle or the newest Titan rockets. And for the future, Orbital Sciences is proposing to build a reusable payload transfer vehicle—a fancier version of the TOS—that would ferry cargo from the shuttle or NASA's space station to higher orbits.

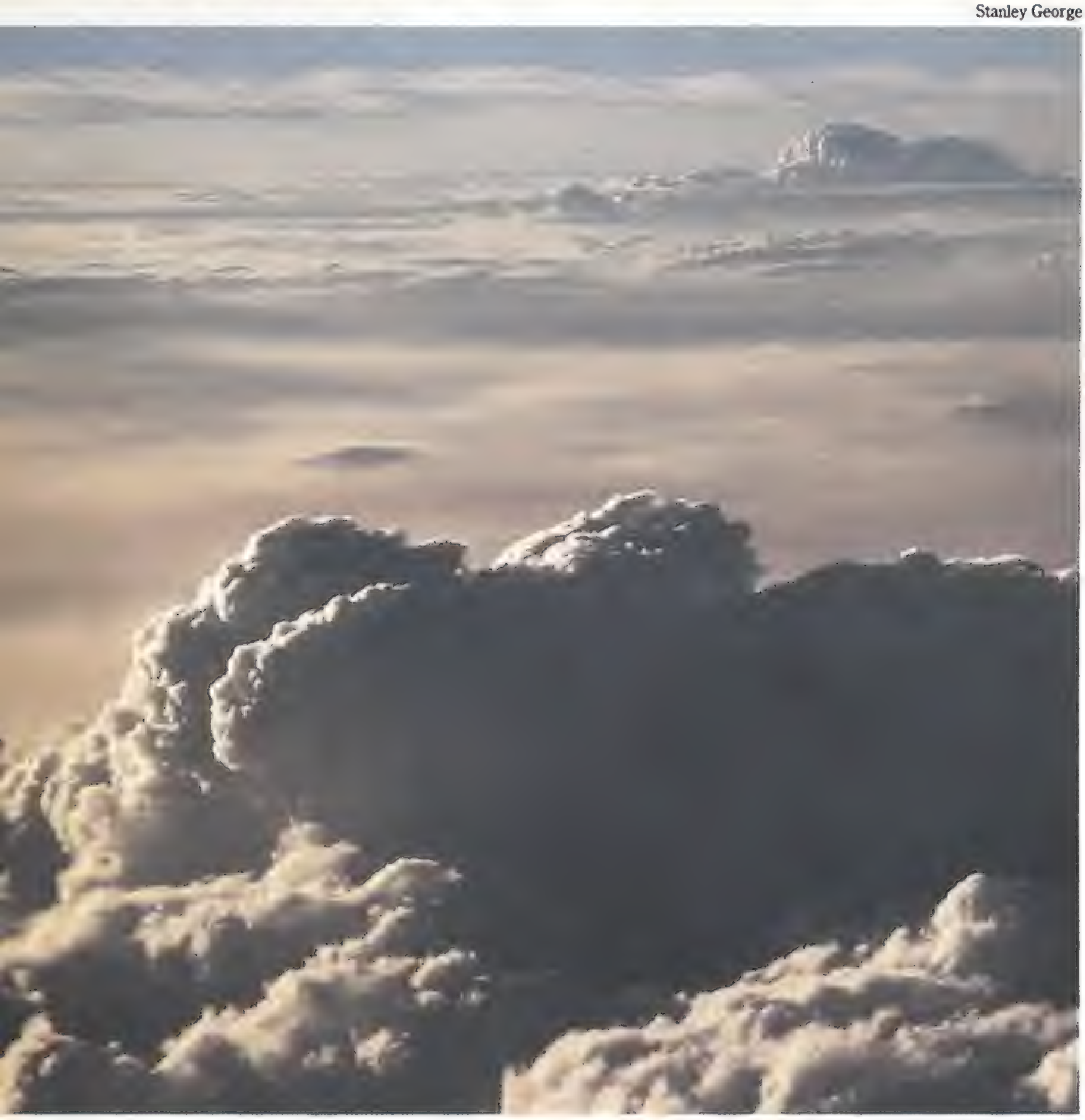
Meanwhile, NASA recently raised the possibility of postponing the Mars Observer launch until 1992, meaning the agency's payments for that booster could be two years late. The company has advised its financial backers that the earliest they will start seeing returns on their investments is 1988, instead of 1987 as promised. If Orbital Sciences is worried, Ferguson, Thompson, and Webster would never admit it. Decked out in pinstripes with viewgraphs in hand, smiling even though they're not on the way to the bank, grumbling in private over still being labeled boyish, playing by the rules even though the rules keep changing, the three are determined to make it into the big leagues. And they're happy to share their enthusiasm with potential converts to the space-business cause.

For example, when a Stanford University business-school class recently finished a case study of Orbital Sciences, the trio flew to California to meet with the group. This was the first such class they knew of that was dedicated to the study of space commercialization, and they promised the 26 students that their names would be engraved on the first TOS to be launched in space. After putting the Mars Observer on its interplanetary track, this booster—already christened the U.S. Spaceship *Fred C. Alcorn* after the company's first investor—will head into a perpetual solar orbit, passing close to Earth and Mars every couple of years, according to Thompson, and lending the Stanford classmates a weird sort of immortality.

As far as its founders are concerned, Orbital Sciences is well on its way into space—a company with only about 30 employees but big ideas. "We can pull off that board meeting in space by the year 2000," Thompson concludes with a sigh. "I don't know exactly when, but we'll manage somehow."

I Do Windows

Stanley George



I do some of my best thinking at 40,000 feet, in an airliner held aloft by unseen forces. At these heights, the apron strings that tie body and mind to Mother Earth unravel and fly apart. The planet curves away beneath us, no longer a world but a spinning sapphire floating serenely. Look up, and we are practically bumping our heads on the floor of space—another 40,000 feet or so and we would be in the realm of daytime darkness.

I recently had this experience in spades, flying Qantas Airlines halfway around the world to Australia. Along the way I learned a great deal about which end is up—literally.

Everyone "knows" the world is round, that we are all stuck on the globe by gravity like cloves in a Christmas orange. But our senses rebel. It seems absurd to think that when I talk on the telephone to someone in Sydney and we both drop our pencils, they fall in opposite directions.

And so we persist in believing that our own "up" is universal. We in the Northern Hemisphere feel we're on top of the world. Australia seems aptly named Down Under. But in truth, there's no good reason why you couldn't call the South Pole "top" and the United States "down under."

Flying 21 hours "up" in the air and having "down" flip 180 degrees under your feet makes you reevaluate such parochial beliefs. As Guy Murchie reminds us in *Song of the Sky*, the direction of down in space is "a matter of taste." There is no "down" in the universe—there's only "toward." And whether we're pulled toward objects by the familiar but little-understood forces of gravity, or whether that apparent attraction results from the curvature the objects carve in space-time, remains one of the most profound mysteries of modern science.

There are other surprises. For nearly 16 hours we are over ocean—an endless expanse of blue Jell-O covered with whipped cream. Yet we still tend to think of our home planet as "land." So it's always something of a revelation to see with your own eyes the world as a great ball of water. The Earth is really a vast underwater home for dolphins, sharks, whales, sponges, coral, tuna, plankton, and who knows what else. But here we sit on our crummy one-quarter, singing "We Are the World." The heck we are.

Twelve hours or so into the flight I ask the attendant if it's Tuesday yet. Did we pass the International Date Line? "Sure," he says, poker-faced. "Didn't you feel the big bump back there?"

It's funny because our sense of time—like our sense of direction—is so arbitrary up here. Let's see, if it's 2 p.m. Friday in New York, then it's 6 a.m. Saturday in Sydney. Which means it's later than you think. It also means that clock time has no proper place in the cosmos. Hop off the Earth, and the whole idea vanishes like a mirage. Suppose you could circle the globe in 24 hours and continue to do so, nonstop—it would always be 2 p.m. (or 6 a.m., or whatever). Only the date would change.

Of course, you needn't journey all the way to Australia to see interesting things from an airplane window. Once, I was flying

from Boston to New York, having spent the afternoon with a physicist at the Massachusetts Institute of Technology who was trying to unravel how the various forces of nature fit together. Looking out my window, I could see how barrier islands that seemed to be separate were actually linked by submerged spits of land—connected in ways invisible to the groundling.

I thought of Muriel Rukeyer's poem "Islands": "The bathers think/ islands are separate/ like them; O for God's sake/ they are connected/ underneath." The physicist, I realized, was trying to accomplish what I had done merely by boarding an airplane—seeing the hidden links, attaining a better point of view from which previously obscure things would become clear.

Indeed, you can see much from above that is ordinarily hidden. There are markings that trace Earth's natural history, such as the neat curves carved by rivers. People have left their own markings—fields plowed in perfect rectangles and spirals, baseball diamonds, strip mines. It seems as if a child with ruler, protractor, and compass had drawn all over our globe.

Mainly, you get the impression that the Earth's surface is alive—which, of course, it is. Highways branch into roads and streets, like veins and arteries. Rivers carry the blue blood of the planet to plains and valleys, where it collects in pools and lakes. Patches of new greenery sprout in the midst of barren brownness. The face of Mother Earth is not smooth like a young girl's; she has earned her wrinkles. Rugged mountain ranges are a reminder of the formidable forces involved in the ongoing collision of continents, and gentle hills attest to the constant scouring of wind and rain.

Every city, every region, bears its own special markings. Swooping down on Sydney, you see the city's affluence in its swimming pools, red terra cotta roofs, harbors, marinas—all with white sailboats tugging at their moorings like dogs on leashes, waiting to be taken out. New York is forbidding, a phalanx of stalagmites. San Francisco is soft, tan hills, bridges, large bays shimmering blue and welcoming.

Geography mirrors social context. (Or is it vice versa?). The neat markings of the Midwest reflect geographical boundaries drawn precisely along lines of latitude and longitude: a simple, clean-cut world. But venture east or west and the contours become amorphous, complicated, confused. The boundaries look less carefully laid out than accidently spilled—so much tangled spaghetti. Cities look like integrated circuit boards, branches reaching out everywhere from their nervous centers.

I try to imagine ordinary people going about their daily lives down there, hauling the dog to the vet, sitting in meetings, taking showers, dying, falling in love. Grounded, I often look up at airplanes passing overhead and try to picture people fastening their seat belts and putting up their tray tables, taking a last swig of scotch. Normally, our brains compensate for the small images that distant objects make in our eyes by making them seem bigger, more normal. A man 20 feet away still looks man-sized, even though you can cover him completely with your thumb. But our brains weren't built to make size-distance adjustments at 20,000 feet. The perceptual leap is too far. That's why no matter how hard we try to imagine the reality, airplanes in the sky and cities on the ground will always seem like toys.

Of course, sometimes you look out the window and there are just clouds. Just clouds? A friend likes to pose this question: How would you suspend 100 tons of water with no visible means of support? The answer: build a cloud. The bottoms of the billowing cumulus are cut off so cleanly that they seem like froth on the surface of a bubble bath. In truth, the cloud begins at the ground. Steaming upward like water vapor escaping from a boiling teakettle, the cloud remains invisible until it reaches the condensation level, where the air is suddenly too cold to hold moisture. Puff! A cloud is born.

And why are clouds always white? In fact, anything chopped up finely enough is going to appear white, because the billions of tiny surfaces reflect all the colors of the rainbow—or white.

I learned early in my career as an airline passenger that there's a lot of interesting optics up here. For example, the tiny oval windows in the doors of some airplanes are prisms that refract sunlight into spectral colors, painting rainbows around the wings and engines. Most aircraft windows are badly scratched, which makes them good diffraction gratings, spattering sharp splinters of pure color on the plastic panes. Rainbows also appear around the sun as you pass through a cloud. Sometimes, an astute passenger can even see the full circle of a rainbow in a storm below.

As I contemplate all this, the attendant comes by and asks me to lower the shade on my window. Not on your life! The other passengers don their headphones and escape into the fantasy of the in-flight movie. What a shame, I think, when the spectacle outside is so much more fantastic.

I have a horrifying thought: when space flight becomes routine, will passengers bury their thoughts in their magazines or newspapers, forgetting to look out the window?

—K.C. Cole

"One of the biggest obstacles was getting flight insurance."

My Little Cabin in the Sky

When Air Force captain David G. Simons set a manned-balloon altitude record of 102,000 feet—19½ miles—on August 19, 1957, he concluded two years of training, including several preliminary ascents, for a program called Man High. The program, under the direction of Colonel John P. Stapp, provided the nascent American space program with the means to study previously unknown conditions, particularly cosmic radiation, that might one day affect astronauts.

Simons sought to disprove the earlier findings of Swiss scientist Jakob A.G. Eugster, who reported that oat seeds he sent aloft for exposure to cosmic radiation had major mutations that showed up in three generations of plantings. Eugster also sent samples of his own skin aloft for exposure to cosmic radiation. The samples, when grafted back onto his body, developed dark granules, indicating cancerous growth.

Time and further research eventually sided with Simons: humans could safely venture beyond the atmosphere.

The 36-inch-wide, 89-inch-high aluminum gondola also served as a floating research lab from which Simons could observe the stars from above the murk of Earth's atmosphere. Simons would discover with horror just how well it would allow him to study large weather formations.

This excerpt from Simons' book, Man High, *tells of the second (and more dramatic) half of his 32-hour, three-minute journey from Cosby, Minnesota, to the farmlands of South Dakota.*

My eyes were totally absorbed by the most startling sight they ever have seen. Unless I some day fly far into space I doubt that I will find a sight to equal the panoply of constantly changing color that enveloped the earth for an hour before sunset.

To the west of me the sun still perched as a brilliant white ball above the earth, separated from the white haze of the horizon by a narrow band of dark space. But to the east, the direction the capsule now faced, the sun already had set for the people below. They were in semidarkness. The ground had a formless slate-gray appearance, like a flat rock in shadow at the foot of a hill. But up the hill, in the sky above this darkened earth, the atmosphere glowed with the colors excited by the lingering light of the sun.

Paradoxically, I was still suspended in the full light of the sun, and to my back, somewhere over Colorado and the Dakotas, it still bathed the earth. But in front of me, over Lake Michigan, Wisconsin, and Minnesota, it was setting. And a curious reversal of night and day met my eyes. High in the atmosphere, where the sun still shot its rays, the ever-deepening blue sky was acquiring a greenish, sunset tinge. But below it, closer to the earth, was a giant demarcation line which looked like a faded rainbow arching from south to north across the eastern horizon. And beneath the line was the darkness of night covering the earth below. The daylit sky was above, the darkened sky below. And as the sunset progressed, the rainbow arch rose ever higher, drawing with it a curtain of blackness.

Where the darkness had not yet fallen, the changing sunlight majestically shifted its colors through the atmosphere, deepening here to a fiery red, fading there to a salmon pink, then to a pale yellow. Above the slowly changing colors was a layer of blue so clear that it was as if someone had lifted a veil from an ordinary blue sky to leave it polished and bright and clean with no scattered light to diffuse it.

Below me now I could see the massive cloud system that had caught my attention earlier in the afternoon. It offered a fantastic sight as the thunderheads began to pick up the last glowing red rays of the sun, casting red silhouettes like forges before the glowing heat of a furnace. The clouds, probably 45,000 feet below me, were themselves another 50,000 feet above the earth, and this halfway reference gave me, for the first time, a true feeling for the enormous height at which my capsule was floating.

By 9 p.m. only a thin and short red crescent of afterglow remained. It held above the gray curve of the western horizon for an hour to show me where the sun had set.

Close behind the setting sun trailed Venus, earth's closest neighbor and most earthlike of all the planets. Next came Jupiter, a far larger planet. But it did not give the astral color display that Venus had offered. Instantly I wondered if my position in the sky had changed radically between the two observations. I checked the altimeter. Its needle was turning downward. I was losing altitude.

I had expected to drop somewhat due to the contraction of helium from cooling when the sun went down. But now my descent appeared to be too fast.

Glancing into my mirror, I saw the reason for the rapid loss. The cloud system which had moved between me and the earth below had cut the balloon off from the earth's infra-red radiation, and as a result, the helium in the balloon was cooling far faster than it would on a clear night. I tripped ballast switches number one and number two, cutting away two 50-pound batteries which had been exhausted and were no longer useful except to be dropped. There was a gentle upward spring to the capsule as the weights fell away.

I turned to the telescope. Jupiter was still far enough above the horizon for a sighting if I could only get it in the narrow field of the eyepiece. But to look was almost sickening. The balloon still was losing altitude slowly. And as it dropped it passed through varying eddies of air which turned it first one way, then the other. I could not find Jupiter in the eyepiece, but I did catch the untwinkling brilliance of the stars above as they moved across the field of view of the rotating telescope. And their appearance startled me. One normally does not think of the stars as being colorful, but only as points of light in the sky. Now I saw red stars burning a steady red, and blue stars were distinctly blue. They were not mere points of light, like blinking bulbs lighting a darkened street. They were untwinkling, living, colorful objects with places of their own in the cosmos.

But my awe of the universe quickly shifted to the awesome sight below me. It was a little after nine o'clock and now the storm that had moved in so rapidly had cut me off completely from the earth. It was a

thing of great beauty, but I was thankful for my altitude, because it contained the seeds of destruction.

Altitude: 87,000 feet, but still dropping slowly. Should I drop more ballast now to level off? I had already cut away my exhausted batteries. There was still some juice left in number three and number four. To drop them now would cut into my power reserve. I'd have to be patient. This descent should stop pretty soon.

I was not worried, but the steady descent did concern me. In order to get "good seeing" with the telescope, I wanted to spend the night above 85,000 feet where there is virtually no water vapor in the atmosphere. I also wanted the balloon to hang steadily at one level above that altitude because ascent or descent seemed always to cause the maddening rotation that made telescoping impossible. Even more important to my comfort and safety, the capsule's temperature-control system was designed to function best above 85,000 feet. The paper and mylar insulation on the outside depended on a near vacuum to keep heat trapped within the capsule. If I descended to a denser level, the honey-combed layers of paper would fill with air that would conduct the cold to the skin of the gondola. The temperature outside was now 65 below zero. I had no desire to have that chill creep into my space cabin.

Even so, the thought of a chill had some appeal. Capsule temperature had been over 75 since 4:30 in the afternoon, and I knew it was steadily eating into my efficiency. I was soaked with sweat and recognized that I was bitterly tired. As I looked at my portholes, I cursed with a sense of futility. They had fogged over. Now a new barrier stood between me and the observations I wanted to make. My attention wandered. My body ached. My mind cried for rest and relief. Each time I wanted to look out for a meaningful observation I had to fight through a heavy cloud of fatigue and grasp for the energy to wipe the moisture from a porthole. I felt as if I was rapidly aging, speeding through the years from 35 to senility in a few short hours.

But if anyone had asked me if I wanted to get out I would have been appalled. I recognized my aches and feelings of frustration as symptoms of the frailty of my body, not as reasons to justify discouragement over floating alone high above the earth. It was frustrating and damnably uncomfortable, but instead of permitting dejection to take hold, I became even more determined to break through the futility, to submerge the aches and fight off the fatigue.

Irritated with the nagging rotation of the still-descending gondola, I lethargically wiped the moisture from one window and tried to observe the sky around me. But it was virtually impossible to hold anything in my field of view. Looking out only a single window, unable to shift my eyes to another porthole when the gondola swung around, I saw a panorama but I could never keep my eyes fixed on one part of the sky long enough to study it carefully. The balloon was still descending slowly. At 10:30 I dropped a now exhausted 50-pound battery pack to check it.

Simons' trip was like spending 32 hours in a spinning phone booth.

Department of Defense

For a few minutes my interest perked up. Out of the single cleared window at 10:42 I saw the glorious tail of Mrkos' comet, twice as long and brilliant as it is seen from earth.

But soon my attention shifted back to my own discomfort. The stresses of heat and fatigue were now so completely overriding my objective desire to make star observations that I could no longer fend them off. At 11:30 I wearily called the van by radio.

"N-C-A Three One, this is Three Eight. I'm just too tired to go on for a while. With your permission, I think I'll try for a half hour's sleep."

Colonel Stapp was manning the radio in the van.

"Roger, Dave," he called. "Better to spend some time resting than fighting yourself. You'll be able to accomplish a lot more after some sleep."

Just before drifting off to sleep I noticed the altimeter: 85,000 feet. It was still dropping slowly.

I slept.

"N-C-A Three Eight . . . N-C-A Three Eight . . . N-C-A Three Eight . . . Do you read me? Do you read me?

I was only dimly aware of a voice, sunken and far away, calling a familiar number. Groggily, I opened my eyes.

"N-C-A Three Eight . . . Do you read me?"

It was Vern Baumgartner. But his voice was on the threshold of inaudibility. I shook my head. It was still impossible to hear him. I checked my receiver. Somehow, while napping, I accidently had turned the volume control down. It was midnight. Vern was calling for the hourly report. One by one I checked the items on the list and read them off to him. The temperature had dropped while I slept, and the capsule was comfortable. No longer did I have to drag my every action through a veil of exhaustion.

A glance at the altimeter confirmed what I had seen before dropping off to sleep. It was at 75,000 feet now and still descending, slowly edging down toward the rising storm below. The thunderheads were beautiful, but I had no desire to see them from within. One of the first lessons even a novice light-airplane pilot learns is profound respect for the violently churning, up-and-down wind currents in thunderstorms. In an airplane, controls are direct and effective, and one can steer clear of storms. But in a balloon, the only controls are up and down. I was still safely above the massive storm, but I could no longer consider it only as a thing of beauty to be studied. Each puffy,

anvil-shaped finger above the storm was a thunderhead whose swirling stem contained natural forces as violent as the fiercest hurricane: winds that could dash my silent balloon about like a child's plaything, and electromagnetic forces whose slashing charges of lightning could turn the Man High capsule into an incinerator.

The balloon still was at least 15,000 feet above the storm. But I knew I must ballast. I could not continue the relentless descent.

It was a touchy and delicate problem. For above me the polyethylene of the balloon had now cooled to 95 degrees below zero. It was as brittle as a thin sheet of glass. When I cut the 50-pound battery away, it would be like snapping a tense rubber band. The shock of the sudden loss of weight would race up the suspension lines to the brittle balloon above. Would the jolt be enough to break it?

Tense but still, lest I add to the shock by moving my own body, I reached for the ballast switch. And holding my breath, I flicked it. The capsule jerked sharply. It would take about four seconds for the shock to run up the lines to the balloon. I counted.

"One, mississippi . . . two, mississippi . . . three, mississippi . . . four, mississippi . . . it must be there."

My buttocks tensed, waiting for the precipitous feeling of falling that would surely come instantly if the balloon had burst. Four seconds later, the shock returned from the balloon. It had taken the jolt without breaking.

"N-C-A Three One. The battery is away. All's well."

Again I slept. But hardly had my eyes closed when I was awakened with a start.

The gondola was plunging and spinning. "Great God," I thought. "The bottom has fallen out!" I was plunging God knows how fast into a storm that would surely kill me.

What happened? The balloon must have split. As suddenly as the precipitous fall began, it stopped.

With the jerky motions of anxiety I turned to look at the altimeter. Just a shade under 70,000 feet. What's happening?

I tugged a Kleenex from a box at my side and nervously scrubbed a porthole to look quickly around me. To the southeast something was obscuring the stars, blotting them from view. Shifting my eyes and straining, as if trying to make out the shadow of a man against an unlit window, I made out its shape. It was a thunderhead, reaching higher than I ever imagined a dense cloud could rise. It was every bit as high in the sky as I was.

Now I knew why the balloon had dropped so wildly. It had been caught in the downdraft of a puff of wind thrown up from one of the thunderheads below. If the cloud to the southeast were at my altitude, there probably were similar thunderheads very close beneath me. I was sitting right on top of a massive storm.

"I'm trapped," I thought. "Another gust like that and I'll be sucked right into it."

Fear raced through me with the speed of nervous shock, like the chill that comes instantly with an icy blast of wind.

My antenna certainly was trailing within lightning range of the clouds. If lightning did not hit first, the treacherous winds of the thunderstorm could suck me down, to be slammed about unmercifully and then shattered by a fiery bolt of lightning.

"I've got to get hold of myself," I thought.

Urgently, I pressed the radio foot switch and called [Otto] Winzen. Even the comforting sound of his voice would help. I explained my position carefully.

"Are you certain about the altitude?" he asked. "If you're at 70,000 feet I don't see how you could be so close to the thunderheads."

"I know no one has ever seen these things so high before, Otto, but they are here and I'm right on top of them. At least one of them extends even higher than my altitude. I'll have to cut away some ballast, even if it does cut my power reserves."

"You'd have to drop a hundred pounds to do any good at your altitude, Dave. That will be an enormous shock to the balloon. I don't know if it can take it."

"I don't like the idea any more than you do. But I have to do it," I quickly replied. "I'd rather take a chance on breaking the balloon and pray that it won't break than sit here and just wait for this storm to pull me down or hit me with lightning."

Pembrook, the renegade third Wright brother, at work on the first anti-aircraft gun.

"Roger, Three Eight," Winzen called. He sounded as frightened as I was.

Meteorologists had never before observed thunderheads rising above 45,000 feet, although they suspected the stormy protrusions might rise to 55,000 or even 60,000 feet. I had become the first man to see thunderstorms at 68,000-70,000 feet.

I pressed the switches firmly. The capsule jumped as the batteries fell away.

And I counted. One second. Two seconds. Three seconds. Four seconds. The shock had hit the balloon now. I was not falling. It had held up. Four seconds later the shock returned.

I watched as the altimeter showed a rapid gain in altitude. In two minutes the needle stopped climbing. The balloon had leveled off. I had climbed only a few hundred feet.

At least my hazard was not increasing.

My edginess at being so close to the thunderheads below almost vanished as I sat entranced by the changing colors in the sky. For two hours now the balloon had drifted like wood on a clear, calm lake, holding steadily at one altitude without rotating one way or the other. I was working with the telescope when I felt a sudden twinge, then the capsule began to rotate rapidly. The altimeter needle fell off: 70 . . . 80 . . . 100 feet in a minute's time. The storm was just beneath me. Again I had been caught in a turbulent gust of wind from a thunderhead below. The urgency of fear returned. Then the descent stopped.

I still had to drift by the massive storm front. And after that, descent alone would take three hours. Like it or not, I had to sit it out, hoping for the sun to warm the balloon quickly and expand the gas so that it would lift me out of the thunderhead's violent reach.

Fervently as an apostle awaiting the Lord's return, I watched for the sun to peek over the horizon. Soon it announced its coming, more beautifully even than Gabriel's horn could do.

With the warm, friendly glow of sunlight, the balloon began a slow but steady climb back to the earth's ceiling. For the moment, at least, I was safe. Back to higher altitudes with the warm balloon, I would again catch the slow five-mile-an-hour westward wind that had propelled me before.

* * *

Now the balloon began a slow descent. I knew I had to establish a 400-foot-per-minute rate of descent in order to pass through the jet stream as quickly as possible when I reached it. If I was descending too slowly, I might hang in the strong easterly wind just long enough to be blown back into the thunderstorm. But if I descended much faster than 400 feet per minute, my speed would be so high by the time I reached the ground that the gondola would crash rather than land.

My troubles were not over. Again and again the steady descent rate slowed. And again and again I pressed the valve switch to release more gas. My fingers were now tiring from pushing against the strong spring tension of the switch.

For an hour I continued valving, waiting, valving, waiting. Each time I valved the descent would increase, then it would drop again. By 3:30 I had descended only to 70,000 feet. But slowly the descent was creeping up to the 400 feet per minute I had to have.

Suddenly my right arm felt like it was burning up, and I looked quickly at it. A bead of intense light was burning through the material of my pressure suit. It was from the telescope. Somehow during the descent, the telescope mirror had picked up the sun's image and was beaming it through the eyepiece directly down on my arm. Hurriedly, I turned the mirror away from the sun. A possibility which I had never considered had very nearly caused a fire and disaster just as success was almost at hand.

At 4,000 feet the balloon slipped through a filmy layer of clouds, tired wisps floating slowly above the earth. I hit the ballast switch and felt a snap as one of the emergency battery packs fell away. The balloon slowed. Three minutes. Three and a half minutes. I hit another ballast switch and the last 100 pounds dropped off. Now there was no power save one small battery that would trigger the switch to cut away the balloon and open the upper dome when I landed.

Below me was a softly plowed field. The stubble of a newly harvested crop of flax made a beardlike pattern on the ground.

It was rising toward me now. Faster. Faster.

My hand, poised over the balloon-release switch, flew away from the switch with a shock. Groggily I shook myself. The balloon was dragging the gondola across the rough furrows. Fumbling, I reached the switch again and pulled it. The huge plastic bag, lightened immensely now without its space-capsule load, lifted away.

The capsule toppled on its side, but my safety straps held fast.

I was on the ground safe. Looking around inside my capsule, a reluctance to end the flight crept over me. Despite the frightening problems I had become such a part of the sky that now, once more bound to earth, I wished to be up again, far above this plowed field.

Slowly I tripped the switch that released the upper dome and crawled out of my space-armored capsule.

Department of Defense

It took three million cubic feet of helium to lift Simons 19½ miles above the planet.

A warm sun, the smell of freshly harvested flax, the feel of soft loam beneath my feet. Nostalgia for the stratosphere left me. I was glad, now, to be back.

Less than 100 yards away, bent across the neck of an old field horse, came a farmer in faded blue overalls. Astride the horse with him was a youngster, his son.

Tugging off my helmet and the sweat-soaked nylon liner beneath it, I called:

"Hello! How are you today?" I could think of nothing more dramatic to say.

"Howdy," called the farmer in taciturn voice as he and the boy slid from the bare-backed horses.

"Grab the reins, boy." He turned to his son.

The youngster held the horse's head down to keep him from shying at the sound and sight of an approaching helicopter. It was Winzen, with Stapp, Archibald, and Foster dropping to a landing on the field.

"Look," cried the boy, excitedly, "there's a helicopter. I always wanted to see one of them."

The space capsule which had just returned from 32 hours and three minutes at the ceiling of the world lay unnoticed at his feet.

Below from Above: Aerial Photographs. *By Georg Gerster. Abbeville Press, 1986. 192 pp., color photographs, $35 (hardbound).*

Shooting great aerial photographs requires more than pointing a camera out the window of an airplane and going "click." Merely launching a photographer into the third dimension with a functioning camera does not guarantee beautiful or significant photographs. The addition of altitude provides nothing more than a novel perspective: it is just as necessary to look and work for a great image while aloft as it is while anchored to the ground.

Georg Gerster puts a Christo sculpture into perspective from the air.

After years of shooting pictures all over the world from the air and on the ground, I can attest to both the difficulties of aerial photography and the success of Georg Gerster's book.

There are many ways in which an aerial shoot can fail. The weather, for instance, is often less than the photographer hopes for: Murphy's Law applies to meteorology, too. The challenges of obtaining the necessary permissions, finding a cooperative and savvy pilot, and renting an airplane are often more difficult than the actual process of exposing film.

Permission to fly over and to photograph a given site or event can be difficult, if not impossible, to obtain. Photographing Paris from the air is illegal, for example. To cover the start of the Gordon-Bennett Balloon Race from the Place de la Concorde several years ago, *National Geographic* circumvented this prohibition by placing a photographer in a police helicopter.

Making sharp images requires steady, stable flight. Pilots unfamiliar with the task of flying an aerial photographer often think that high-speed maneuvers worthy of the Blue Angels are the order of the day. Nothing could be further from the truth. If the pilot fails to locate the airplane at the right spot in the sky with the machine under control, then not even the greatest aerial photographer can make adequate pictures.

The airplane of choice—a high-wing Cessna—often is not available. In Iceland I once photographed through the rear baggage door of a low-wing Piper Navajo. I had to lie on my stomach to do this, and the rope tied around my waist was supposed to lessen my chances of falling through the opening. To get the job done, the aerial photographer must be flexible, adaptable, and willing to sacrifice some dignity.

Only after all these regulations and arrangements have been dealt with is it time to take off and see the world with a photographer's eye. The elements of light, composition, and perspective which make great images on the ground are equally important to aerial photographs. In *Below from Above,* Georg Gerster presents images from around the world which demonstrate both his mastery of the mundane problems of launching himself into the right place at the right time, and his ability, once aloft, to make great photographs.

Below from Above is divided into sections containing six or eight pages of photographs followed by two pages of extensive captions. Each photograph occupies at least one full page, with an occasional blockbuster image spread across two. Gerster shoots straight down at the ground, and because many of his pictures contain no reference point to provide a sense of scale, it is often difficult to determine whether an image is of a small object shot from a low altitude or of an enormous object photographed from great height. This occasional confusion lends a sense of mystery that is both provocative and humorous.

Looking at the photographs in this book, I can almost hear Gerster yelling at the pilot to move the airplane up or down, left or right. When the light is perfect and he barely has time to speak, I can feel him willing the airplane into position. When Gerster is photographing the ground below on a beautiful, clear, calm evening, I sense his triumph and his feeling that he would trade places with no one on Earth.

—James A. Sugar has been a contract photographer for National Geographic *for the past 15 years, and holds a commercial pilot's license.*

The Leading Edge. *By Walter J. Boyne. Stewart, Tabori & Chang, 1986. 232 pp., b&w and color photographs, $29.95 (hardbound).*

Walter Boyne, former director of the National Air and Space Museum and founder of *Air & Space/Smithsonian,* is a prolific writer and a veritable walking encyclopedia of aviation to boot. His latest work depicts aviation's history from the Wrights through the futuristic Air Force/National Aeronautics and Space Administration mission-adaptive wing that will change shape in flight.

That may sound like an exercise in redundancy: already, there are more than enough aviation history books languishing in the permanent "sale" section of bookstores. But *The Leading Edge* is different. Most immediately obvious is the fact that it is awash in illustrations far removed from the standard "Wright *Flyer,* three-quarter view" formula. Moreover, Boyne shares his contagious love of his subject as he chronicles crucial breakthroughs in aviation technology and looks at where they are taking us. His central thesis is that "the mechanical devices . . . of aviation have a beauty of their own, an inherent logic that qualifies them not only as inventions of genius but as works of art, and . . . behind each one lies a veritable soap opera of human drama."

The soap operas include little-known anecdotes about the eccentricities that inevitably accompany genius, as well as descrip-

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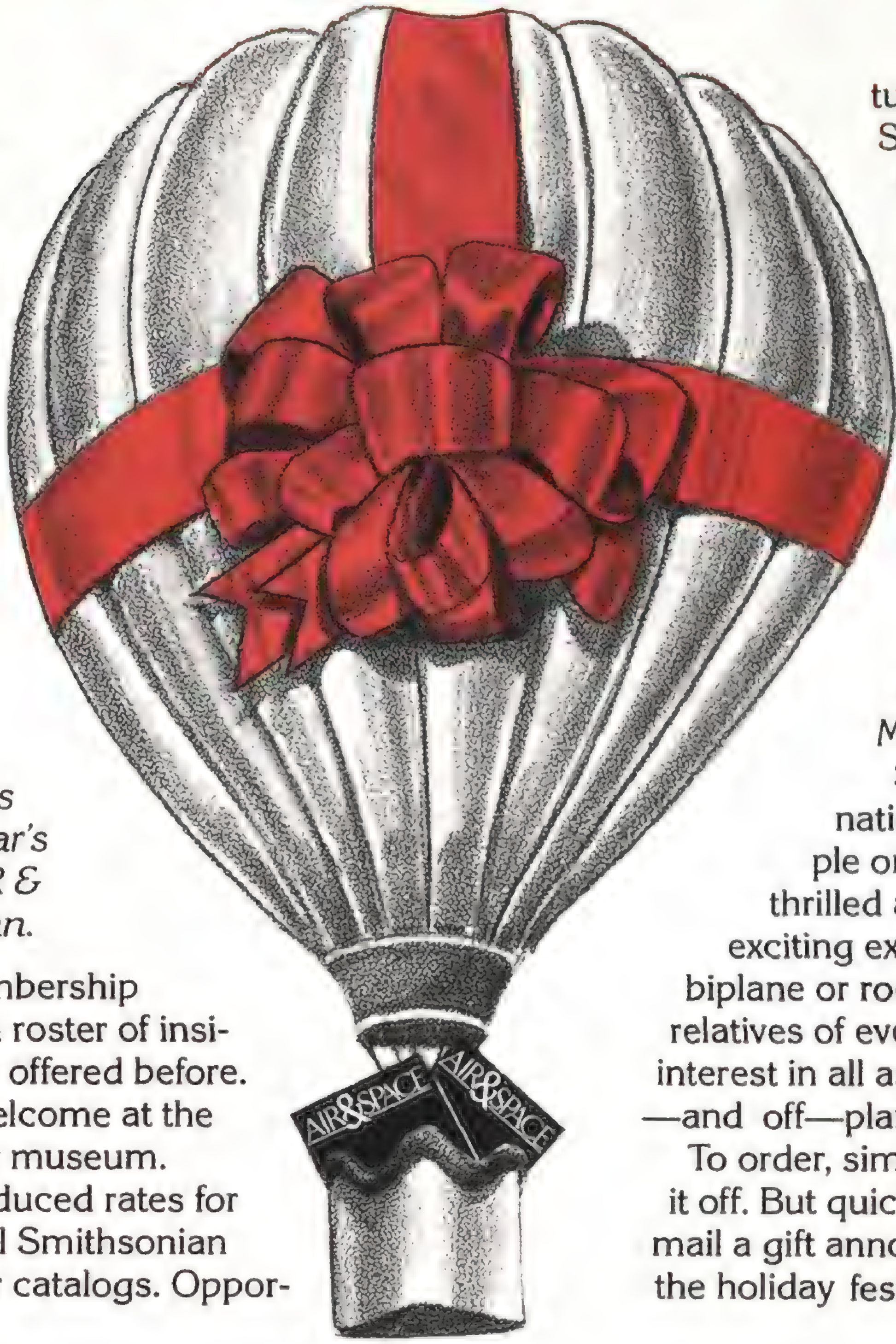

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tions of the designs these quirky mentalities produce. For example, inventor J. V. Martin is described as "a small, gutsy, volatile man. . . . Martin was a ship's captain, a pioneer aviator, an inventor, a manufacturer, and (repeatedly) a litigant." His 1917 Kitten aircraft was "a remarkable little biplane with genuine retractable landing gear, hindered only by the fact that it could not fly." Boyne also writes about radial engine designer Charles Lawrance, who when asked if he resented being ignored after Lindbergh's transatlantic flight was made with a Wright radial engine, replied, "It doesn't bother me; after all, nobody remembers the name of Paul Revere's horse."

The photographs, many never before published, are rich in color and design. Several of the early black-and-white pictures have been meticulously hand-tinted, adding warmth and a sense of surrealism to the records of the pioneers' feats—and failures. It appears that all the illustrations were selected for their composition and color rather than their expository, "educational" value, another reason the book should appeal to those outside the usual airplane-fancier circle.

The book's one distraction lies in the design of the pages that begin each new chapter: on several, half the title is in large, dark print, with the remainder tacked on like an afterthought in small, widely spaced letters. It's a minor but noticeable irritation to the eye.

Woven into the drama and comedy of aviation's technological evolution is the story of the cultural bonding of a society with its inventions. Boyne tells us how the Wrights' biplane captured the public's imagination and instantly became an icon, despite the fact that hardly anyone had seen it fly and government, business, and science initially paid it little heed. "Appreciation for . . . change is a peculiarly human attribute," the introduction reads, and the closing chapter reminds us that the human spirit is always the true leading edge.

—Patricia Trenner

The Cambridge Atlas of Astronomy. *Edited by Jean Audouze and Guy Israël. Introduction by Sir Bernard Lovell. Cambridge University Press, 1985. 432 pp., color and b&w photographs, $90 (hardbound).*

Astronomy is unique among the physical sciences in that its raw data, the light from distant celestial objects, often produce images of stunning beauty that appeal equally to eye and mind. Thus, one can appreciate the splendor of the sky without totally comprehending its mysteries.

Moreover, the heavens are accessible to everyone, from the backyard stargazer using nothing more than his own eyes to the sophisticated amateur with advanced telescopes at her command.

And, as new technologies open new windows on the universe, the resultant discoveries dazzle and delight us all. In the past three decades, thanks to advances in both ground and space instrumentation, we have learned of a bizarre and wondrous range of phenomena almost impossible to imagine: black holes, neutron stars, gravitational lenses, and exploding galaxies.

On another level, we know that the laws of physics that determine the nature of astronomical objects are identical to those underlying the physical processes of everyday life. Indeed, clues to the creation and evolution of all matter in the universe may be found among the stars.

The Cambridge Atlas of Astronomy is equally appealing on the esthetic and intellectual levels. One magazine for amateur astronomers has already dubbed it "the astronomy book to end all astronomy books." This may be a slight exaggeration, since the apparently insatiable popular interest in astronomy surely means competition for the title will continue. Still, with over six dozen distinct sections written by 44 different contributors, more than 1,000 illustrations (two-thirds of them in color), a weight of six and a half pounds, and a price tag to match, this book will be a hard act to follow.

Indeed, if you had but one astronomical reference in your library, this could be it. Comprehensive, complete, and yet concise, this atlas might better be described as a one-volume tutorial on modern astronomy and astrophysics.

The book begins with descriptions and depictions of our nearby neighborhood: the sun and the individual planets (including Earth) and their moons. This section is most like a conventional atlas, for here our understanding—or at least our mapping—of the various bodies is most complete. The text then moves logically and progressively deeper into space following the hierarchical structure of the universe itself: stars to galaxies to clusters of galaxies. Along the way, there are brief stops to investigate related topics: the history of astronomy, the search for extraterrestrial life, the role of particle physics in cosmology, and the prospects for future research in space.

Despite its solid scholarly tone, the text is consistently clear; it is free of jargon while avoiding the gee-whiz quality that mars much popular writing about astronomy. This is all the more remarkable since, while not specifically noted, much of the text must be in translation.

The Cambridge Atlas of Astronomy *reflects on the beauty and meaning of the stars.*

The first edition appeared in France in 1985. Although the Continental origin reveals itself only in a slight emphasis on European accomplishments in astronomy, the publishing time lag resulted in the book's one fault: some spectacular developments of the past year—the close encounters with Halley's Comet, the flyby of Uranus, and the several significant advances in cosmology and galactic distance measurements—

are not reported. Of course, as British radio astronomer Sir Bernard Lovell notes in his introduction, the present age has produced "a sequence of revolutions in astronomy that has undermined the accuracy and lasting qualities of any astronomical atlas so far published."

In truth this particular atlas will probably have considerable staying power due to the strength of its illustrations alone. Few astronomy books can match the quality of its photographic reproduction or the clarity of its diagrams and charts. The selection draws on both the historical and the modern, dipping into the vast international reservoirs of spacecraft images, as well as the classic, large-plate photographs from the world's largest telescopes and the almost psychedelic images now produced by the combination of electronic detectors and computer processing. More important, the marriage between text and illustration is near-perfect.

In a concluding section on the symbiotic relationship between new instrumentation and new discoveries, the editors note that "the Universe may be sending us information in a form still unsuspected," and they urge astronomers to "keep looking." The material for a new atlas may be lurking in the night sky, but until it arrives on Earth, *The Cambridge Atlas of Astronomy* will remain among the best guides to our current understanding of the cosmos.

—James Cornell is publications manager at the Harvard-Smithsonian Center for Astrophysics.

Images of Flight: The Aviation Photography of Rudy Arnold. *By E.T. Wooldridge. Smithsonian Institution Press, 1986. 160 pp., b&w photographs, $16.95 (paperback).*

From the 1920s into the 1950s, a persevering photojournalist named Rudy Arnold recorded the world from, and of, airplanes. His base, New York City, hosted some of the great aviation developments and events of those decades: the grand transoceanic flying boats, record-setting flights by the top pilots of the era, and wartime fighters and bombers.

Arnold, initially shooting for the *New York Graphic* and later as a freelancer for some of the top magazines and newspapers of his time, relied on airplanes as perches from which to shoot the news of the day. But with equal relish, it seems, he recorded the airplanes and pilots that passed before his lenses. This volume, written by the chairman of the National Air and Space Museum's Aeronautics Department, features a

Rudy Arnold captured the news of his day from airplanes.

smattering from the broad collection of Arnold's aviation-related images in the Smithsonian Institution's archives.

Wooldridge's book is by no means a biography. Instead, the book presents a history of aviation as seen by Arnold, with over 100 black-and-white photographs and 10 color images. Wooldridge has culled an unusual and evocative assortment. Several pages of text grace each chapter.

From this selection it's clear that Arnold was no "art" photographer: his work was documentary. But certain images stand out. A girlish Amelia Earhart, smiling shyly, stands by her Electra. The *Hindenburg,* a gigantic charred smudge, rests on the sand the day after its disaster. A Grumman Avenger skims just above the wake from one of five speeding torpedo boats.

The text contains dramatic accounts of the lengths to which Arnold often went to get a picture. Once he rode along in a Coast Guard flying boat sent to rescue an injured sailor: high seas made both landing and takeoff risky, and severely damaged the airplane. Another time, Arnold had planned a head-on interception between his photo plane and a new Grumman Wildcat to shoot it straight-on. The airplanes nearly collided, but Arnold's evaluation of the flight was: "The mission was flown perfectly to the n*th* degree." However, the pictures that resulted from these gutsy ventures aren't included in this volume.

Wooldridge offers readers unusual tidbits of aviation history throughout the text. We learn, for instance, that Laura Ingalls, whom Arnold photographed many times in the 1930s, held a record for having flown 980 consecutive loops. She set a record for barrel rolls, too: 714 in succession.

Overall, it is Arnold's photography that predominates. His efforts can be especially appreciated from a picture of him and his equipment before a flight in 1939. An array of big cameras and cases surrounds him. A Leica hangs around his neck. He certainly wasn't blessed with the zoom-lensed, automatic-exposure, gyro-stabilized, lightweight cameras available today.

Wooldridge mentions briefly that Rudy Arnold himself was a pilot, although most of his photography was done with other pilots at the controls. Unfortunately, the book fails to explore the relationship between pilot Arnold and photographer Arnold, and how knowledge of flying—understanding the capabilities and limitations of the airplane—gives an airborne photographer an advantage. Even today, some of the better of Arnold's successors—William Garnett, Russell Munson, James Sugar, and Baron Wolman come to mind—both fly and shoot. And little technical detail is offered about Arnold's work or equipment. Such information may simply not have been available, since Arnold died 20 years ago.

His work, however, remains as pleasing and informative today as it was the day it hit the streets on page one of the *Graphic* or on the cover of the *Saturday Evening Post.* Whether you're a photographer who likes airplanes, an aviation history buff, or a pilot who relishes images from above, you'll enjoy this book.

—Berl Brechner has been an aviation writer and photographer for 14 years, and is a four-time winner of the Aviation/Space Writers' Association's Photojournalism Award.

The Voyager Missions to Jupiter and Saturn. *Produced by Jet Propulsion Laboratory for NASA. Distributed by Finley-Holiday Films, (213) 945-3325. 30-minute videotape. $34.95.*

Voyagers 1 and 2 had astronomers in hog heaven. For years the planets Jupiter and Saturn had been zealously guarding their secrets, until the two probes, lonely travelers on the currents of space, began to lift the veil. This 30-minute video provides a quick summary of what they found.

"One tends not to believe the reality of what is there," said one scientist after reviewing the evidence from the Voyagers' cameras and instruments. It was, indeed, much like science fiction come to life. There was Jupiter, a gas giant with storms that last for hundreds of years. There were its moons: Europa ("a cracked billiard ball"), Io (looking like a space pizza, with volcanoes coughing sulfur and gas into space), large Ganymede, scarred Callisto. Galileo had seen these moons through his telescopes, but mankind's knowledge of them had not increased much until our fragile emissaries made their flybys.

Four years and a billion miles past Jupiter, first Voyager 1 and then Voyager 2 passed Saturn, with its mysterious rings

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and orbiting court of moons. Again, the space travelers provided rich information about the planet, much of which is still being analyzed.

At one point, as it swung behind Saturn, Voyager 2's camera platform jammed. Two days later the JPL technicians managed a two-billion-mile repair job and pointed the camera in the right direction. Think about that the next time you're faced with an easy terrestrial job like replacing a muffler.

The videotape does not go into extensive detail about the Voyagers and their discoveries: what we get instead is a quick cram course. Naturally, the most intriguing material is the actual photography, especially the time-lapse images that strikingly demonstrate the motion of the gigantic Jovian storm known as the Great Red Spot. The images taken of Saturn's rings and each planet's moons are also fascinating.

If anything, *Jupiter and Saturn* could use even more material from the Voyagers' cameras. The videotape employs computer simulation and paintings (occasionally without clearly identifying them as such), but neither medium can match the impact of the actual photographs taken of worlds millions of miles away.

Voyager 2 passed Uranus early in 1986, providing a landslide of scientific information that this videotape does not discuss. Next stop for Voyager 2: Neptune.

—*Tom Huntington*

Orbiter. *Space Shuttle Simulation Software. By Spectrum HoloByte Inc., (303) 443-0191. $49.95. Available in Macintosh 512K and IBM PC versions.*

"*Orbiter*, this is control . . . ," chirps the simulated voice emanating from your computer, and you're off on a space shuttle mission to deploy the Hubble Space Telescope or snatch an ailing Westar satellite for repair. Whether this trip should be called a game or a simulation is for the user to decide, but *Orbiter* has genuine value for anyone curious about how NASA's space shuttle flight operations are conducted.

Orbiter turns the computer screen into various parts of a shuttle cockpit, and the presentation on the Macintosh is a triumph of graphic programming. (In fact, it duplicates current practice in aircraft electronics by using a single screen to produce a wide variety of displays.) By moving a pointer, you select images of buttons and switches in response to commands from "control," which speaks with an accent that sounds like a Scandinavian who went to school at the University of Southern California. The point to *Orbiter*, if there is just one, is to learn the sequence of commands in the craft's check list well enough to fly a mission without the help of the autopilot. It is unlike a game in that you do not win points or compete against an opponent. Instead, the thrill of victory is experienced in the successful completion of a "mission": deploying a payload, such as a satellite, or rendezvousing with some orbiting body.

The makers of *Orbiter* have equipped their shuttle with a manned maneuvering unit (MMU) that can be launched from the spacecraft and used to retrieve and deploy objects. It has its own set of controls and viewing windows, and using the MMU, you can fly away from the shuttle vehicle and look back at it. There's even an accurate representation of the Earth's surface with outlined land masses that can be viewed from either the MMU or the shuttle's windows. The shuttle's remote manipulator arm also comes with a complete set of controls to move it and operate its hand.

Not all the craft's equipment works, though. For obscure reasons, the shuttle is equipped with laser and missile weapons that are described in the somewhat quirky manual as "included for use with simulation scenarios which may be developed at a later date." One wishes one could have been a fly

"Who told you you could fly?"

on the wall when the creative crew at Spectrum HoloByte wrestled with that one. For now, the pacifists are in command: the manual states, "You will not be able to destroy any objects with these weapons."

The missions are designed to duplicate as closely as possible an actual shuttle mission, but with an important difference: you can "compress" the real mission time by factors as great as 20 to one when things get a little slow, as they do, for example, while waiting in orbit for the moment the autopilot computes is correct for your deorbit burn. The manual suggests that beginners fly the training mission until some of the functions become familiar. Even so, there are procedural pitfalls aplenty. When the funny voice of control suggests that you open the payload bay doors, your natural tendency to point to the "open" button on the door control earns you only an alarm beeper; you must first power up and then unlock the doors before they can be opened. For most of the flying, there's an autopilot to handle various "programs" entered on cue through the keyboard of the control panel. Thus, the entire launch operation as far as insertion into orbit places you in the role of spectator—unless you opt to fly manually, which is considerably more difficult. There are any number of ways to fail in your mission: botch the landing, run out of fuel and burn up in the atmosphere . . . it can be humbling.

If you look to *Orbiter* as a kind of flight simulator based on a spacecraft, you're likely to be disappointed. Practicing with the reaction control system thrusters to produce simulated translation (along axis) and rotation (around axis) movement can be educational, but the takeoff and landing phases are much less satisfying. Perhaps the toughest challenge you'll encounter is using the thrusters to stabilize the shuttle's angle of attack at the correct values during the reentry phase. Your only cue is a single numbered read-out—you get no help from any visual reference, which makes this bit of flying an experience in luck. And don't run out of fuel in the process.

I liked the way the system displays the shuttle's flight path in profile during the launch and the moving map of its ground track once in orbit. Flying the MMU is also fun, particularly on the mission calling for a run out to the orbiting space station. You can call up a view from somewhere near the moon so that you can see the positions of the assorted objects in orbit in relation to the shuttle—and you'll need it. But I had hoped for a simulation of approach guidance, with a directional radio beam to fly by means of some instrument and a set of cues. Instead, this model provides only the suggestion that an approach profile be flown so that a given ratio is maintained between certain numbers.

Altogether, I suppose I logged a couple of hundred hours on *Orbiter*—and much of that time "compressed," I'm grateful to say—and I found that the simulation began to grow on me after a few flights. The ability to skip over the routine of the launch segment and go straight into an orbital mission by making a simple menu selection helped a lot. But I also got the impression that this software was designed by a person or a group of people who have an ulterior motive. It has certain qualities that suggest to me that it was created, in part, to impress other programmers. I'd guess *Orbiter* is the equivalent of an entry in its designer's résumé, and were I an employer looking for someone who can write code for a simulation—not a bad business to be in, by the way—I'd want to talk to the people behind *Orbiter*. Whether it's a game or a simulation is arguable, but it's definitely an advertisement for what its creators can do. That they elected to apply their considerable talents to software that teaches us about the space shuttle is our good fortune. Few other sources of this kind of education are anywhere close to being this much fun.

—George C. Larson

The Sounds of Jupiter and **Sounds of Saturn.** *With narration by Dave Krebs. Produced by TRW Inc., 1980 and 1982. Two sound sheets, approx. 3 minutes each, $3 each. Available by order from Sounds of Space Group, 1022 Calle de Acacia, Redlands, Calif. 92373.*

Now, for the space buff who has everything, there are the sounds of space. These 33⅓-RPM sound sheets let you eavesdrop as instruments on the Pioneer and Voyager spacecraft record solar wind, radio wave emissions, and other phenomena.

Our planetary neighbors are surprisingly musical. You certainly won't mistake Jupiter for Joplin, or confuse Saturn with Stravinsky, but when the narrator describes one category of sounds as a "chorus," the description seems surprisingly appropriate.

The narrator's commentary includes a great deal of helpful and interesting information. I, however, would have enjoyed these sound sheets more if the explanations had taken the form of an accompanying text which one could read while listening to the eerie planetary noises.

Imperfections and all, though, *The Sounds of Jupiter* and *Sounds of Saturn* are fun, and certainly unusual.

—Katie Janssen


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Orbis Helps the World to See. *Elaine de Man* is a freelance writer whose work has appeared in *Omni* and *Technology Review.* She lives in Alameda, California.
Further Information: To contact Project Orbis, write to 330 W. 42nd St., Suite 1900, New York, N.Y., 10036, or call (212) 244-2525.

The Electric Jet. *Fred Reed* is a syndicated military columnist with Universal Press. He has also written on military and general subjects for *Harper's* and *National Review.* He wrote "Dark Flight" in *Air & Space/Smithsonian,* June/July 1986.
Further Information: The General Dynamics F-16 Fighting Falcon by Jay Miller (Aerofax, Austin, Tex., 1982).

Flight Fantasia. *Frank Getlein* is a longtime Washington art critic and the author of 35 books. He is also, by his own admission, a swell dancer.
Further Information: G.B. Tiepolo, His Life and Work by Antonio Morassi (Phaidon Publishers, New York, 1955).

The Trouble with Air Traffic Control. *Thomas Foxworth* has 22 years of experience as a pilot for a major airline and is the co-author of the novel *Passengers* (Doubleday, New York, 1983). He has a long involvement in aviation safety activities.

Space Geniuses Wanted: Apply JPL. *Stephan Wilkinson*'s writing credits in-

Michael Crawford

clude screenplays for three Academy Award-nominated documentaries. His last article for *Air & Space/Smithsonian,* "Who Is Bryan Allen?" appeared in the June/July 1986 issue.
Further Information: JPL and the American Space Program: A History of the Jet Propulsion Laboratory by Clayton R. Koppes (Yale University Press, New Haven, Conn., 1982).

Homemade Satellites. *Nancy Shute* is a Washington, D.C.-based writer specializing in science and the environment.
Further Information: Space Communication by Stanley Leinwoll (J.F. Rider, New York, 1964).

Moon? Boom! *Kendrick Frazier* is a science writer specializing in astronomy, space exploration, and planetary science. He is a former editor of *Science News* and author of four books, including *Solar System* (Time-Life Books, Alexandria, Va., 1985).
Further Information: Birth of the Moon by Lewis A. Manson (Dennis-Landman Publishers, Santa Monica, Calif., 1978).

Christmas in the Azores. *George Long* was working for Pan American Airways when the company started its transatlantic service, and in 1939 was its assistant manager in Horta. Now retired, he lives in New Port Richey, Florida.
Further Information: Flying the Oceans: A Pilot's Story of Pan Am, 1935–1955 by Horace Brock (Stinehour Press, Lunenburg, Vt., 1978).

Entrepreneurs in Space. *Junius Ellis,* formerly a senior editor at *Money* magazine, is now a New York-based freelance writer. His article "Voyager" appeared in the October/November 1986 *Air & Space/Smithsonian.*
Further Information: Space Commerce: Free Enterprise on the High Frontier by Nathan C. Goldman (Ballinger Publishing Co., Cambridge, Mass., 1985).

Once an Eagle . . . *Gene Basel* is the author of *Pak Six: A Story of the Air War over North Vietnam* (Associated Creative Writers, La Mesa, Calif., 1982). He lives in El Cajon, California.

Home Is Where the Hangar Is. *Patricia Trenner* is an associate editor at *Air & Space/Smithsonian.*

I Do Windows. *K.C. Cole* is a science writer living in Port Washington, New York. Her latest book is *Sympathetic Vibrations: Reflections on Physics as a Way of Life* (William Morrow, New York, 1984).

In the Wings . . .

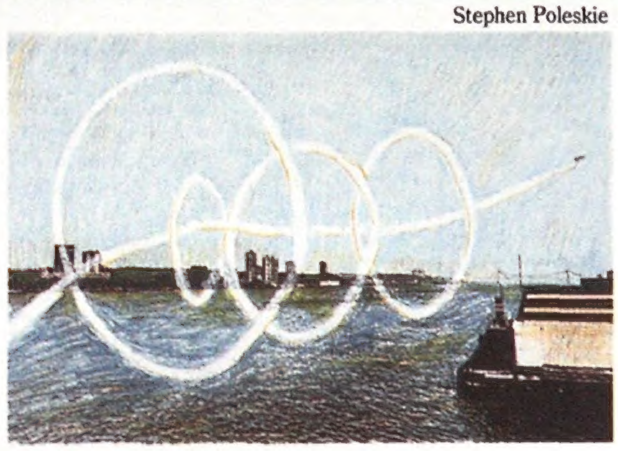
The Twilight of an Airport—New York's Floyd Bennett Field is one of aviation's ghost towns: abandoned years ago, its runways sprout weeds and its hangars slowly decay. But the old flying field just won't fade away. Now it's a combination park and playground, and people are rediscovering its past. (right)

Ken Kerbs

Finding the Way to Douglas Corrigan—Searching for the famous "wrong way" flier took writer Phil Cohan to Texas and California before he located the man, still hale, and recorded Corrigan's remembrances.

Ten Years of Marisat—It won't make the front pages, but the maritime satellite system is now entering its second decade of service, providing worldwide communication to ships at sea. They're even talking about adding similar services for airliners. After a shaky start, maritime satellites blossomed into a model of global cooperation.

Stephen Poleskie

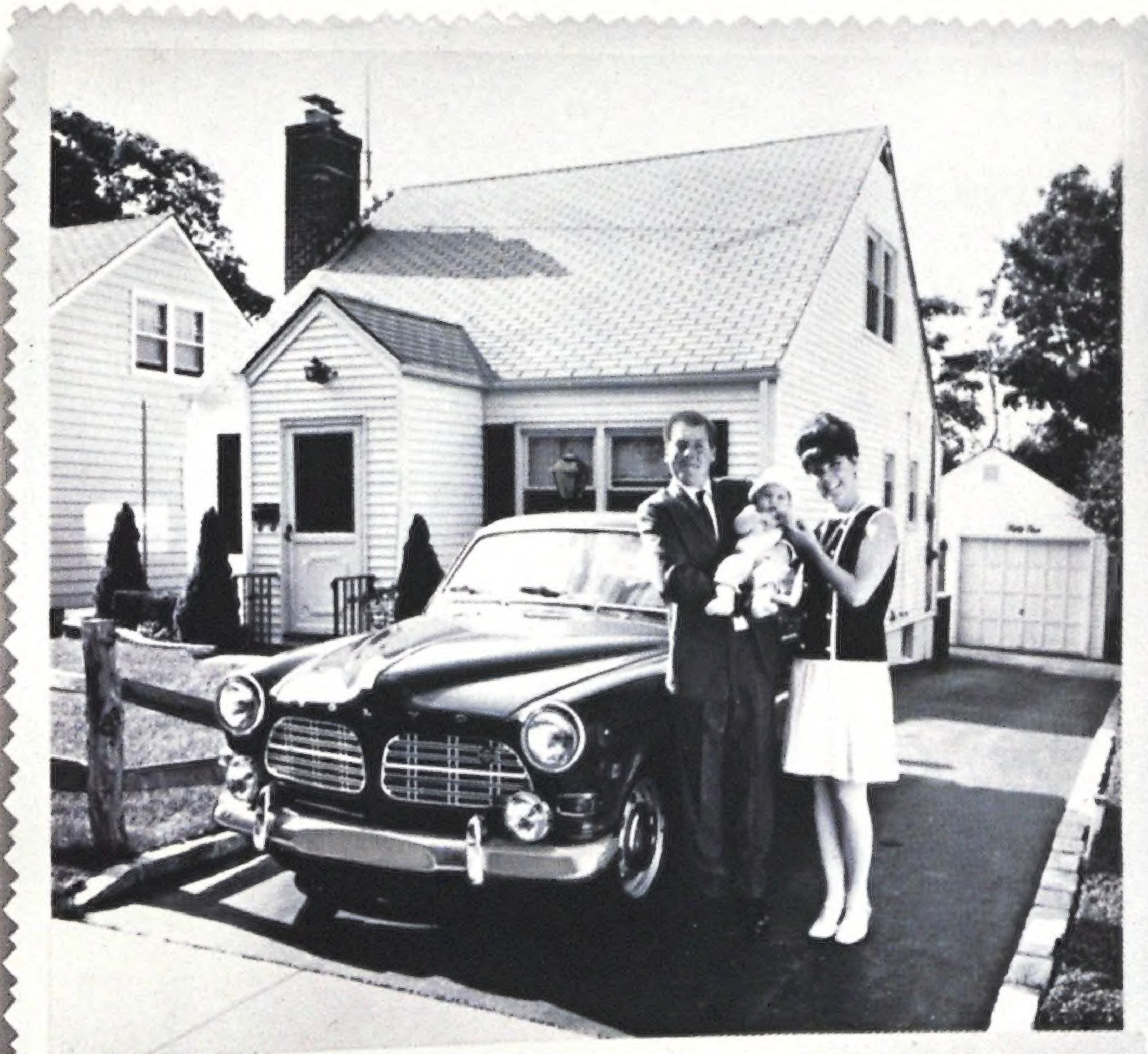


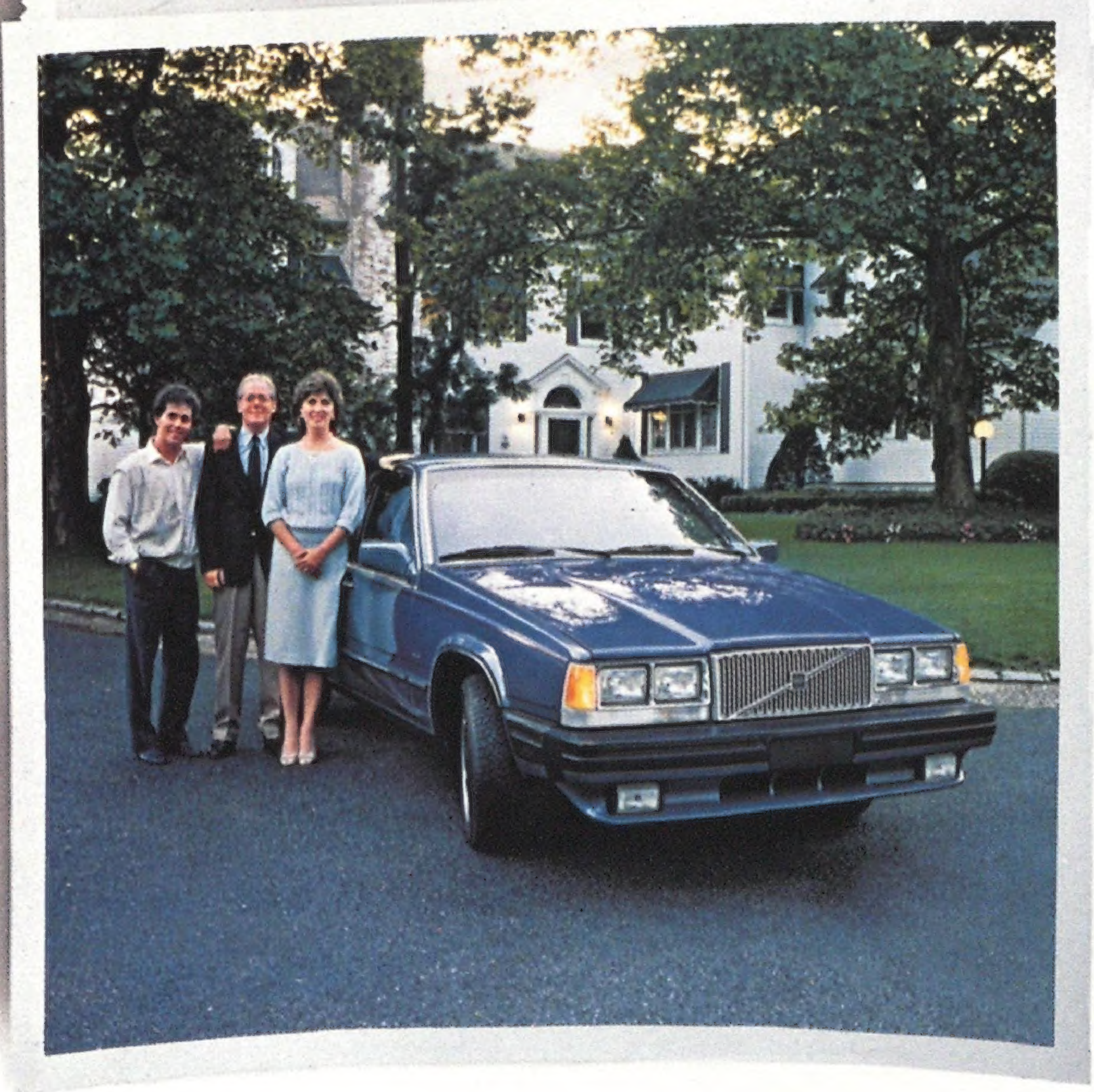
Smokin' Steve Poleskie—He's an artist, he's a pilot, he's a kind of Rembrandt of the skywriters. For this heavenly "painter," the sky is just one big empty canvas.

Backpack Rockets—Strap on the posterior propulsor that turns a human into an aircraft. It's not much bigger than a hiker's standard rucksack—but *much* louder. And the people who use these back burners to take a flying leap are definitely a different breed.

Alan Bean Revisited—The happiest ex-astronaut you've ever met, Bean never really left space. He's been recreating it ever since he departed NASA's halls to take up palette and brush. And his paintings are gaining him an increasing audience as his reputation grows among those art buffs who know what they like.

THE CAR FOR PEOPLE WHOSE MEANS HAVE CHANGED BUT WHOSE VALUES HAVEN'T.





Back when you had precious little in the way of means at all, you may have been one of those pioneering souls who bought a Volvo.

It was the perfect family car. Spartan? Perhaps. But also very sensible. A Sherman tank with room for six. And a growing reputation for durability and safety.

Both of us have come a long way since then.

You, for example, may have reached that point in life where you view a car not as a necessity so much as a reward.

And we have reached a point where we can create a car like the Volvo 760 Turbo.

A car that surrounds you with every comfort a person of means could want in a car. A turbo-charged phenomenon capable of embarrassing cars much more famous for performance.

Admittedly, the Volvo 760 Turbo is an indulgence.

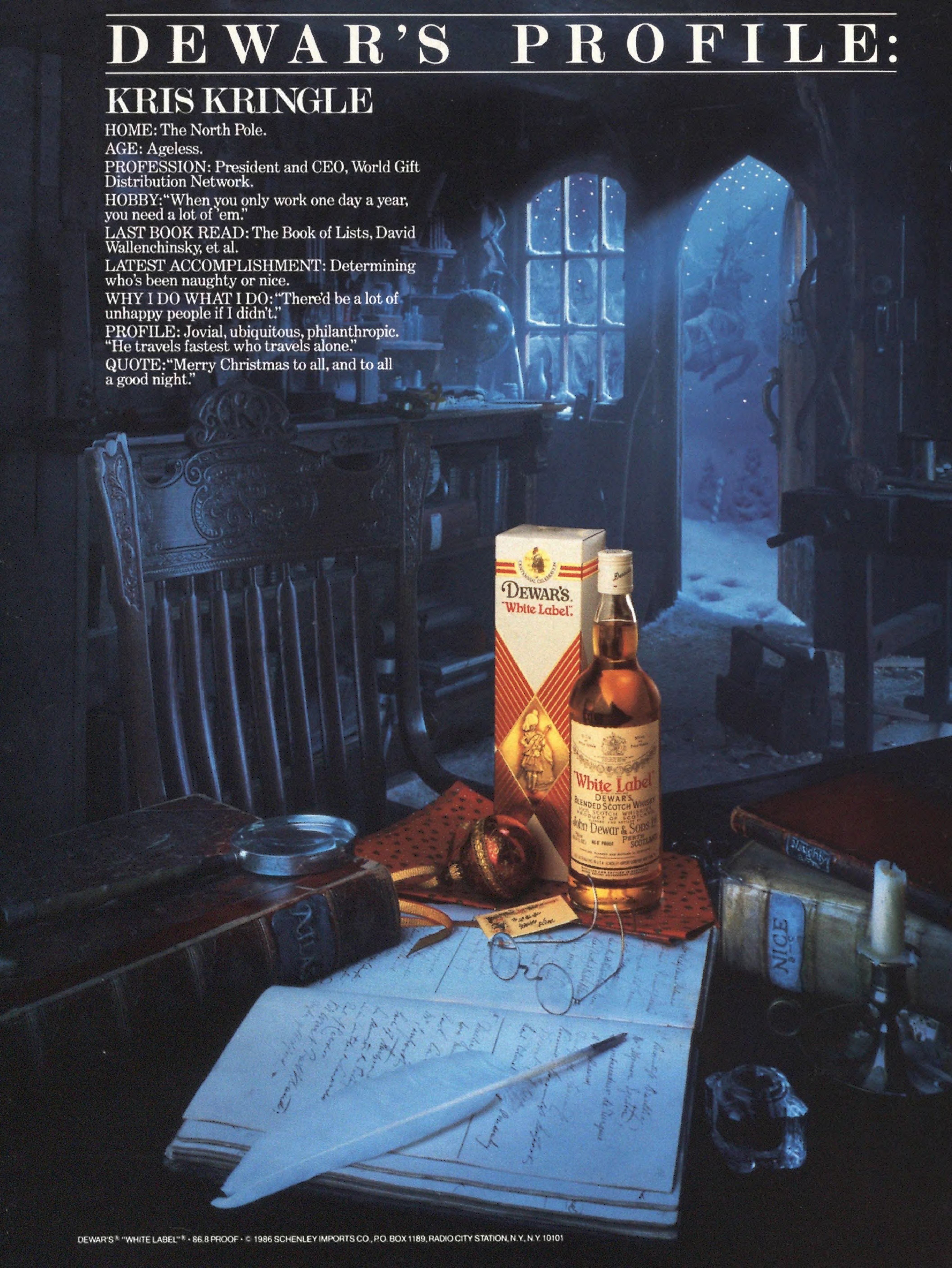
But underneath you'll discover it's still a Volvo. A totally sensible car with an enviable reputation for durability and safety.

A car that lets you indulge your senses.

Without taking leave of your sense.

VOLVO

A car you can believe in.



DEWAR'S PROFILE:
KRIS KRINGLE
HOME: The North Pole.
AGE: Ageless.
PROFESSION: President and CEO, World Gift Distribution Network.
HOBBY: "When you only work one day a year, you need a lot of 'em."
LAST BOOK READ: The Book of Lists, David Wallenchinsky, et al.
LATEST ACCOMPLISHMENT: Determining who's been naughty or nice.
WHY I DO WHAT I DO: "There'd be a lot of unhappy people if I didn't."
PROFILE: Jovial, ubiquitous, philanthropic. "He travels fastest who travels alone."
QUOTE: "Merry Christmas to all, and to all a good night."
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